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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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ROBERT J. THOMAS,

President New England Water Works Association,

1909.

NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

WROUGHT-IRON CEMENT-LINED WATER PIPE.

BY LEONARD METCALF,* CIVIL ENGINEER.

[*Read December 9, 1908.*]

INTRODUCTION.

In the course of the recent water-works valuation suit at Portland, Me., in which the plants of the Portland Water Company, Standish Water and Construction Company, Gorham Water Company, and the Foreside Water Company were appraised, the writer had occasion to look up experience in New England with wrought-iron cement-lined water pipe. A search of the files of current engineering journals developed some articles of interest, referred to in the bibliography appended to this paper, and led to the sending of an assistant, Mr. William L. Butcher, a member of this Association, to interview the superintendents of several of the New England plants upon their experiences with the wrought-iron cement-lined water pipes in their works. The data thus acquired, with certain observations and deductions by the writer, have been brought together in this form in the hope of eliciting a general discussion upon the merits and demerits of wrought-iron cement-lined pipe, by members of this Association, many of whom have had personal experience with it.

TYPE OF CONSTRUCTION.

Two general methods of building wrought-iron cement-lined pipe have been used in this country: the first, known locally, perhaps, as the Goodhue & Birnie pipe; the second, what is known as the Phipps patent.

The Goodhue & Birnie pipe was generally made by riveting up

* Of Metcalf & Eddy, consulting engineers, Boston, Mass.

sheets of wrought iron, single riveted with cold rivets, without any attempt to make the joints watertight, and lining this wrought-iron shell with from ¾ inch to 1 inch of neat Rosendale cement, or cement mortar mixed one part of cement to one part of sand. This work was generally done in a central plant, or at different points along the pipe line, from which the pipe was carried to the trench, there imbedded in Rosendale cement mortar laid along the bottom of the trench, and then covered over the sides and top with a ¾-inch to 1-inch layer or casing of Rosendale cement mortar plastered on with rubber gloves or trowel in the hands of the pipe maker. The trench was generally backfilled immediately or shortly after laying the pipe.

The pipes were made in lengths of 9 feet, and the joints between the pipes were made by means of a sleeve of wrought iron with inner and outer casing of cement, or by making the pipe tapering so that the end of one pipe was fitted into the end of the next. In the larger mains the joints were often plastered on the inside after laying; in the smaller ones, this was, of course, not attempted.

The Phipps patent pipe was generally made and coated without as well as within with a ¾-inch to 1-inch layer of cement or cement mortar, the outer coating being held in place by a thin sheet of wrought iron which subsequently rusted out in the trench. This outer sheet was of distinct advantage, however, as a protection to the outer cement coating in the handling and laying of the pipe.

In a few cases cast-iron bells and spigots have been riveted to the wrought-iron sheets before making the pipe, and the joints have then been made in the ordinary manner with lead tightly calked in place or by the use of cement mortar.

More recently, under the Phipps patent, a type of cast-iron ring has been developed which is driven home in each end of the pipe, — one of the rings being a female ring, the other a male ring, — thus more rigidly holding the end of the pipe and preventing injury to it in transportation and laying, and incidentally making more convenient the placing of the outer cement coating of the pipe, which is made of grout poured into the mold between the inner and outer sheets, with the pipe standing on end. The joint between pipes is made finally by the use of a sleeve as heretofore.

So far as the writer is aware, no cast-iron joint has thus far been developed which has proven thoroughly satisfactory and advantageous from the standpoint of economy.

It is perhaps worthy of note that while blue annealed *wrought-iron* sheets imported from England were used in many of the early installations, in making the later ones steel has been substituted at some saving in cost, though not in durability.

EARLY HISTORY.

A glimpse of the early history or experience with wrought-iron cement-lined water pipe is given in the report of the well-known engineer, Mr. Phineas Ball, of Worcester, Mass., to the city of Springfield, to be found in the report of the Board of Water Commissioners to the City Council for the year 1876, which is quoted below at some length:

Extract from Report of Phineas Ball, dated at Springfield, Mass., January 15, 1876.

"OF WROUGHT IRON AND CEMENT-LINED PIPE IN GENERAL."

"There is always in every community a certain number of intelligent citizens who entertain honest doubts as to the utility of using this kind of pipe. In the minds of many of the citizens of the city, this doubt has existed and still exists. Under various forms during the last two and a half years this want of confidence has been freely expressed by many. After an experience of twelve years in laying and watching wrought-iron and cement-lined pipe, and having examined many samples of pipe removed for various causes, and after examining defects that have appeared under a variety of conditions, and made many inquiries into the immediate cause leading to individual defects, and having consulted with those of large experience with this kind of pipe, your indulgence is claimed to express upon this subject a more direct and a more explicit opinion than I have ever heretofore given in any previous paper or report.

"The durability and permanent usefulness of wrought-iron cement-lined pipe rest upon two principles:

"*First.* Wrought iron possesses the property of sustaining a tensile strain from three to four times greater than cast iron in the same sectional area.

"Ordinary pig-iron, of which cast-iron water pipes are mostly made, will bear a tensile strain from 13 000 to 22 000 pounds per square inch.

"Messrs. Alan Wood & Co., the makers of the iron used upon your water works, furnished a series of tests of samples of iron manufactured by them of the same brand as that which was used in making the pipe, which gave an average of 55 000 pounds per square inch, the tests ranging from 46 000 to 71 000 pounds to the square inch.

"Cast iron is crystalline in its structure, and in casting even the best is 'liable to air bubbles and other defects, which render its tensile strength very unreliable.' Wrought iron is not subject to this peculiarity and in all places where this special property is most needed, wrought iron is now nearly universally used. In a water main the tensile strength is the one that is constantly in use when a pipe is under pressure, the same as in a steam boiler, and is the property that any material of which a water pipe is made must possess in a very high degree in order to be useful for this purpose. Cast iron lacking this high tensile resistance when used for a water pipe, the deficiency is made up in extra thickness of the shell. And further, as experience has abundantly proved, cast iron when used for pipe is subject to decay from oxidation, to provide for which decay the usual practice is to add to the necessary thickness needed to stand the pressure from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch for what is called the 'life of the pipe.' Therefore, in the use of cast-iron pipe, nearly one-half of the metal employed is taken to provide for contingencies that are over and above the requirements for the strength. In this respect wrought iron has a decided advantage over cast iron. The uniformly reliable tensile strength of wrought iron is well known, which property enables a pipe of the requisite strength to be made of it with a very small amount of materials as compared with cast iron.

"The *second* principle is that of the protective power of cement to prevent the oxidation of iron when used underground. In numerous instances this protection has been proved by actual experiment to be singularly effective and complete. In removing small sections of lines of water pipe that have been in use six, eight, ten or twenty years, a great number of lengths will be found to be entirely free from all rust and in such a state of preservation that there seems no reason why such pipe should not endure for centuries. If what is seen as a reliable result upon numbers of pipes removed could be said of it as a whole, its trustworthiness as a permanent water conductor would be assured beyond all question. That the preservative effects of the cement is complete on some pieces and of parts of others and not upon all pieces and every portion of the pipe to which it is applied is the enigma. To make it universally protective where at present it appears only locally so, is the problem presented for solution. To a consideration of this question the attention is directed.

"In the usual mode of making and laying this kind of pipe, my experience has forced upon me the conclusion that there are *two prominent causes which have constantly operated to defeat the protective property of the cement as applied to the iron.* The *first* lies in the fact that the *iron shells have not been made watertight previous to the application of the cement.* Nor is this defect completely remedied either in the manner of lining or laying, as is commonly supposed.

"The *second is, the use of sand with the cement,* as in case of ordinary mortar.

"In the making of the shells, usually, no pretense has been made of making riveted joints watertight. To secure a watertight joint along the riveted laps, reliance has been had entirely upon the cement lining to fill up and make proof against the exit of water any space left open in the riveting. That many pieces are thus made watertight there is ample evidence. But that the vast majority of pipes are not watertight at the riveted laps is too painfully evident from the inspection of any considerable number of pipes taken up that have been in use a number of years. That leaks so large as to require to be 'mended' do occur upon the riveted laps is well known to all experienced in the care of this kind of pipe. This form of 'leak' is not as common as the one at the joint, but still frequent enough to reveal the fact that in this respect it is a defect that needs attention and the application of a remedy. Where one leak of this kind appears on the surface, many more, very small, indeed, occur, only the result of a slight oozing through the cement lining, but sufficient to lift the covering from the outside of the iron and thus commence and continue the oxidation of the iron, until the pipe is ruined.

"My experience has convinced me that leaks of this small character are far more common and numerous upon laps than at joints. That, as a rule, if a joint leaks, sooner or later it will make its appearance at the surface of the ground.

"The second point, that of the use of sand with cement, making it into mortar the same as that used for ordinary stone and brick work, I deem important. It is cement which possesses the peculiar property of preventing oxidation and not sand. Sand dilutes the cement and makes the resulting mass less adhesive when applied to the iron and decreases the tensile strength of the hardened mortar.

"The original patent for this kind of pipe was granted to Jonathan Ball, of New York City, dated December 15, 1843. The claims in the original patent are as follows, to wit, 'What I claim as my invention is the application of hydraulic cement or water cement as a coating upon the interior surface of metallic water pipes to prevent the corrosion and oxidation of the metals of which

the pipes are composed. Also the means by which it is accomplished, as set forth.'

"The original patent was reissued September 15, 1857. In this reissue the word 'cement' is used fourteen times; 'hydraulic cement,' four times, and 'Roman cement,' once; while the word 'sand' does not occur and there is no reference whatever to its use in connection with cement by any form of expression or phraseology used in the document. In practice, however, singularly enough, from the earliest application of the device, the cement was always used mixed with sand in the same manner as in mason work. The earliest recorded line of pipe laid under this patent is one mentioned in the circular of the Patent Water and Gas-Pipe Company, under the date of 1875, by whom it was introduced as being laid in Jersey City in 1845, and referred to in a certificate of Samuel McElery as having been examined by him March 20, 1867. The next oldest line mentioned was laid at Saratoga in 1847, since which time the pipe has been laid in many cities and towns. From time to time various defects appeared, mostly in the destruction of the iron of the pipe by rust. Some of these appeared quite anomalous because no satisfactory reason could be given for their occurrence. For these defects and anomalies the common explanation given was that the cement mortar, meaning the cement and sand, was not properly mixed, or in some cases loam or clay would accidentally get mixed with the mortar and form a very porous mortar, or clay or loam coming in contact with the pipe before the cement covering was applied, by all of which means oxidation was induced. After very diligent inquiry in 1873 and previously of many persons of much experience with this kind of pipe, want of uniformity of mixing the mortar seemed to be the unanimous opinion as the prime cause of all, or nearly all, of the defects observed to that time. On your works the defects of imperfect mixing was remedied, where any sand has been used, by mixing the mortar by machinery.

"An examination of the pipes removed on your works from Chestnut Street and one or two other sections in 1874, and from a hint in a letter from Hon. F. T. Stanley, of New Britain, Conn., dated May 20, 1874, to the Water Commissioners of Fitchburg, in which occurred the following language: 'It is evident to us that the sand that was used here has had more to do with their failure than any other cause, it having more or less admixture of loam,' caused me to investigate the matter anew, and from a different standpoint.

"The use of wrought iron in the construction of bridges, buildings, roofs, and ships has become so common that the subject of its preservation from oxidation has become one of general interest. The causes of rust or oxidation are general; the prevention may

require special means adapted to the kind of structure under treatment. Inquiries into the active causes producing oxidation the most rapidly have been and are still being prosecuted with care and by the aid of science.

" In a paper read by Prof. E. Crace Calvert, before the Literary and Philosophical Society of London, and quoted by *Van Nostrand's Engineering Magazine* for 1871, Vol. IV, page 522, after giving in detail his experiments, he states that ' these series of experiments substantiate the interesting fact observed, — that carbonic acid promotes oxidation '; in the course of establishing which fact he made another series of experiments extending over a period of two years in order to ' throw some light on the curious fact, first published by Berzelius, that caustic alkalies prevent the oxidation of iron.' The main fact substantiated by this series of experiments was ' that the carbonates and bicarbonates of alkalies possess the same property as their hydrates,' that of preventing oxidation. In an article quoted by the above magazine from the *Builder* on " The Preservation and Purity of Iron," Vol. III, page 527, the writer arrives at the conclusion that ' the presence of carbonic acid is necessary for the production of rust,' and mentions the interesting fact of the demolition of the Wriothesly Street bridge on the London and Birmingham extension railway, a bridge which was built in 1835, composed of iron and brick work, that at the time of its being taken down ' it was found to be extremely difficult to separate the brickwork from the girders. It was as easy, or more so, to break the bricks themselves. But when the separation was effected, it was found that this unusual adhesion was caused by the entire absence of rust.' These girders were set in brickwork in Roman cement. The phenomenon of the close adhesion of the cement to the iron is frequently seen in the case of pipe underground, where, on removing the cement, it will be found to cleave off not clean from the iron, but leaving a film of cement on the surface of the iron, and on removing this film, the iron will be found perfect on the parts where this intimate adhesion occurs.

" Another consideration having an immediate bearing upon this subject is the fact established by recent investigations upon the composition of the underground atmosphere. That all soils are porous is a well-known and well-established fact. It has been well ascertained that the pores in the soil, when not filled with water, hold in their spaces air, and further recent investigations show that the composition of underground air in one particular is very different from that of ordinary air. The difference is in the large amount of carbonic acid found in the ground air over that in the atmospheric.

" This subject, in our state, was investigated by Prof. William

R. Nichols, of the Massachusetts Institute of Technology at Boston, during the year 1874. The result of these researches was published in the annual report of the State Board of Health for 1875. The facts here quoted are taken from that report. The normal 'amount of carbonic acid in the outer air may be taken as generally lying between 0.30 and 0.45 part in 1 000.' In the filled land in the Back Bay, in Boston, at a depth of 6 feet below the surface, on August 20, 1874, Professor Nichols found 20.71 parts of carbonic acid in 1 000, or between 46 and 69 times the amount in atmospheric air. This quantity is the largest found at any one time. The average of 31 determinations is 8.83 parts in 1 000, or between 19 and 29 times the amount in the outer air. The lowest amount found was January 5, 1875, when it was only 2.45 parts in 1 000, or between 5 and 8 times the amount in common air. To insure the protection of the iron from the influence of carbonic acid, the coating must be impervious or of such chemical character as to neutralize its destructive agency. The cement may act in both ways; first, by hardening, form an impervious coating, or second, by absorbing the carbonic acid, converting the caustic lime in the cement into a carbonate, or reconverting the mass into elements analogous to those of the natural rock of which the cement was made.

"In testing cement its tensile strength is always found to be the greatest when used pure without an admixture of sand. Sand dilutes the mixture; the more sand, the less tensile strain will it bear, showing that, in a mass of hardened pure cement mortar the particles are more closely united, each to each, than is the case when sand is used.

"One fact is quite noticeable in repairing and removing lines of cement-lined pipes, and that is the very nearly complete preservation of the sheet iron of which the sleeves are made at the joints and the iron of the pipe itself under the joint when perfectly filled. In May, 1870, a portion of the 16-inch main which supplied the city of Worcester was lowered. The number of lengths removed was 164; the number of sleeves, 165. The area of the two surfaces of each sleeve was 6.8 square feet. The total area in the 165 was 1 122 square feet. Upon this entire area scarcely a speck of rust could be found, and the same was to be observed on the pipes under the sleeves. This pipe had been laid six years. The preservation of this iron was partly due to the richer mortar used in filling the sleeve. For a few years past sand has been entirely discarded in 'joint mortar' in laying the pipe. In answer to many inquiries of persons who have the care of works where this kind of pipe is in use, whether rust on and under 'sleeves' is common, I have always been informed that it is very rare indeed to find a sleeve rusted out, or on which rust appears.

"The conclusions, therefore, at present reached may be summarized as follows:

"*First.* That wrought iron as a material of which to make water pipes is much more reliable than cast, with a great economy in the employment of materials.

"*Second.* That the sheet-iron shells should be made watertight before lining with or laying in cement.

"*Third.* That in applying the cement no admixture of sand should be allowed.

"*Fourth.* That owing to the economy with which this pipe can be laid, generally, as compared with cast iron, especially for large sizes, if laid with watertight shells and in pure cement, its use will repay the investment.

"Present experience has brought me to the foregoing conclusions. They are not put forth as final. Further evidence upon the behavior of pipe laid upon the method indicated might lead me to reject the pipe altogether, but until that adverse evidence is received my opinion is that there are many localities in which it may be used for the public benefit. The pipe has many good qualities in its favor, and by a careful study of the facts which relate to its preservation the practice of the principles upon which its permanence rests may be so perfected that it may be as safe to lay this kind of pipe as cast iron. In concluding this subject, I will add that all of the wrought-iron pipe laid on the works this year has been lined and covered with pure cement, without sand, and that more than half of that laid last year was first covered with a layer of about one-quarter inch in thickness before the sand mortar was put on."

In the year 1888 a joint special committee of the City Council of Springfield charged with the investigation "of the problem of how best and most economically to lay a new main from Ludlow to obtain an increased water supply" sent out circular letters to many towns and cities in New England in which cement-lined pipe had been used, asking for information of their experience with it. The result of this inquiry was summarized in an article in *Engineering News*, in Vol. XXI, January to June, 1889.

Extract from "Engineering News," Vol. XXI, 1889.

"A joint special committee of the City Councils of Springfield, Mass., has been chosen to investigate the problem of how best and most economically to lay a new main from Ludlow to obtain an increased water supply. A 24-inch cast-iron main would cost

$225 000, which might be laid to connect with the existing 24-inch cement-lined main. In discussing the question of cast iron *v.* cement-lined pipe, the committee sent to 50 cities and towns a series of questions relating to durability, etc., of cement-lined pipe, and whether or not such pipe was being replaced by cast iron. Forty replies were received and the majority stated that the use of the lined pipe was in disfavor and that it was being rapidly replaced by cast iron. Brooklyn had used cement pipe between 1859 and 1884, but had given it up as unserviceable. Chelsea, Mass., used some such pipe twenty-one years and its condition is fairly good, but cast iron was found to be more reliable and economical. Worcester had a little of this pipe in use for twelve to sixteen years, but the condition is poor, owing to frequent leaks. Hartford, Conn., has 12 miles of cement pipe and has used it twenty-five years but it has been given up as causing more trouble from breaks. Fitchburg, Mass., used such pipe between fourteen and seventeen years, but has given it up as a matter of safety and because the repairs cost more than the change to cast iron. Concord, N. H., has cement pipe laid for sixteen years, and as it is in good condition still adheres to it. Brockton reports cement pipe as all right and no leaks.

"In Pittsfield the water commissioners say that cement pipe has been used since 1855 and its condition is good as far as they know. New Bedford officials consider the pipe unreliable. In New Haven the pipe is considered reliable and no change is contemplated. Meriden, however, sings a different tune. There the cement pipe has been used since 1869 and its condition is very poor. It cannot stand a pressure of more than one hundred pounds. Woburn considers that its condition is perfect with a pressure of between 60 and 95 pounds. It has used the pipe fifteen years and does not contemplate a change. Manchester, N. H., has the pipe laid fifteen years ago, but does not want any more because it bursts. The pipe in Salem has been laid twenty years and is considered good, so they are not substituting iron pipe. Cambridge has not laid any for fifteen years and is substituting iron because there is no doubt of its advantages. New London has laid no cement pipe since 1872, and the commissioner says, 'I would on no account lay a large main of cement-lined pipe, and small mains with only those of the best workmanship and material.' Providence considers the pipe treacherous. Experience in Somerville shows that the pipe bursts, there being an average of eighty breaks a year. Portland, after twenty years' experience, has taken all the pipe up because it could not stand the pressure. In Waltham the pipe has been used since 1873, but as it is beginning to rust, no more cement pipe will be laid. Boston has little of this kind of pipe. It is found to rust and burst.

Malden has some laid twenty years ago, and is substituting iron pipe.

"The answers to the questions as to the amount of water used per capita and the annual receipts were not given in all the slips returned. Those which were given, however, are interesting to compare with Springfield's rate per capita per day of 100 gallons, and her receipts of $129 464 last year. The other cities are as follows:

"*Gallons Used per Capita.* Holyoke, 71; Fitchburg, 60; Taunton, 32; Lawrence, 68; Cambridge, 50; Albany, 100; Hudson, 148; South Framingham, 40; New London, 99; New Bedford, 85; New Haven, 112; Meriden, 50; Woburn, 60; Manchester, N. H., 45; Brooklyn, 66; Jersey City, 100; Chelsea, 60; Worcester, 50; Hartford, 50; Providence, 44; Syracuse, 80; Troy, 130; Lowell, 65; Portland, 150; Waltham, 30; Boston, 80; Malden, 65.

"*Annual Receipts from Water Rents.* Northampton, $22 364; Fitchburg, $51 000; Taunton, $39 444; Concord, N. H., $38 441; Newark, N. J., $340 000; Utica, $70 000; Brockton, $26 000; Pittsfield, $25 000; New Bedford, $51 000; New Haven, $210 000; Meriden, $50 000; Woburn, $26 118; Manchester, $80 000; Lawrence, $80 554; Salem, $52 000; Cambridge, $214 000; Albany, $255 900; South Framingham, $12 000; New London, $23 575; Jersey City, $539 227; Chelsea, $70 000; Worcester, $130 000; Hartford, $145 000; Waltham, $41 127; Boston, $1 540 000; Holyoke, $58 954; Malden, $59 877; Providence, $346 731; Syracuse, $77 000; Lowell, $180 000; Somerville, $90 000."

In 1894 Mr. John R. Freeman, then secretary of the Winchester Water Board, presented a report to the town, to be found in the twenty-second annual report of the Winchester Water Board, January, 1895, in which he discussed the question of the advisability of further installation of wrought-iron cement-lined pipe in Winchester, Mass. Mr. Freeman's conclusions were:

"*First.* Cast-iron pipe can now be laid cheaper than cement-lined. Cast-iron pipe of the size mostly used (6-inch) costs in long lines and easy digging, exclusive of gates and hydrants, which are the same in either case, about 55 to 60 cents per foot for material and labor, all laid; while 6-inch cement-coated sheet-iron costs about 65 to 70 cents under same conditions.

"*Second.* Cast-iron pipe is much the stronger. The computed bursting strength of new pipe is about ten times as great for the cast-iron as for the sheet-iron pipe with its riveted longitudinal seam. The cast-iron pipe is eleven times as thick as the wrought-

iron used, and the greater thickness thus more than offsets the brittleness of cast iron.

"The cast-iron, 'Class B,' is all tested at the foundry by a water pressure of 300 pounds per square inch, and will safely stand the water ram and working strains incidental to 100 pounds per square inch working pressure without danger of bursting under fire duty. Sheet-iron pipe as heretofore used could not be trusted under much more than 50 pounds pressure for domestic draft; and even with this pressure there is always a danger that a temporary quick shutting-off of hose streams during a fire may burst the mains and instantly render the water service useless. Various cases can be cited where such accidents have happened, and there is consequently among many insurance experts a strong prejudice against cement pipe in a public water supply.

"*Third.* The life of cast-iron pipe is much longer than that of cement-coated sheet iron. The thickness of cast iron used for a 6-inch pipe is 0.5 inch. The thickness used for several years past in Winchester for 6-inch sheet-iron pipe is $\frac{1}{2}\frac{1}{2}$ inch; in other words, the cast-iron shell is eleven times as thick as the wrought-iron shell. The sheet iron used in Winchester is no thicker than has been used in some other towns where pipe has rusted out badly. Iron 0.045 inch thick, if it happens to become exposed by the cracking of the cement, will soon rust through.

"A difficulty in the use of cemented sheet-iron pipe is the possibility of imperfect work. One square inch of poor cement covering per 100 feet in length might spoil the usefulness of a whole line.

"Winchester has been, as a whole, much more fortunate in its experience with cement pipe than most towns. Several reasons for the superior endurance of our older mains are very likely the facts that they are under rather moderate pressure from a gravity supply without pulsations of pumping and not subject to the water rams of elevator service, locomotive-tank filling, or the like; and that they mostly lie in firm, well-drained earth. Moreover, it is but fair to suppose that the workmanship and application of the cement covering have been unusually faithful.

"Still we average more leaks per year in the cement mains of Winchester than are found in the cast-iron pipe of all Lowell and Nashua combined.

"The experience of the great majority of cities and towns is that cement-coated sheet-iron pipe becomes so frequently leaky after from fifteen to twenty-five years of use that it is then condemned, dug up, and replaced by cast iron.

"The life of cast-iron pipe properly coated with coal pitch varnish, and with any ordinary earth and water, may confidently be expected to be fifty years, or perhaps even one hundred years for 8-inch pipe or larger. Commonly after five to fifteen years,

tubercles of rust will begin to form, and may gradually cover much of the interior surface with a crust 0.50 or 0.75 inch thick, thereby obstructing the water-way and retarding the flow still more by the roughness. If a pipe of generous size be laid at first, no other particular harm comes from this rusting. There are miles of Cochituate mains in Boston now in active service after a use of nearly fifty years, and which were laid without tar-coating. Cast-iron underground rusts much less rapidly than wrought iron.

" Malden and Melrose have both found it expedient to increase the pressure above that given by gravity from Spot Pond, which is at an elevation about four feet higher than the high-water line of our North Reservoir, and to pump the general supply to a higher distributing reservoir. The tendency of public works is to higher pressure, and perhaps Winchester some day may want a higher regular working pressure. Or, should it be desired at some future day, when a larger high-service reservoir has been provided, to arrange a valve at the central fire station, town hall, or police station (as could be cheaply done), by which instantly, on alarm of fire, the high-service pressure could be turned on the entire town, thus giving about eighty pounds per square inch fire pressure at all hydrants except those on the hill, or substantially the same as the common working pressure of a steam fire-engine, then this cast-iron pipe ' Class B,' which we have adopted for extensions of the past year will be, so far as it extends, perfectly adapted to such use.

" Charlestown was originally piped with cement-coated sheet iron. After fifteen to twenty years the leaks became so numerous that the whole was torn out and replaced by cast iron.

" Fitchburg has for several years past been tearing out each year its cemented sheet iron laid twenty-two years ago and replacing it by cast iron. It has now torn up about 20 miles, and has only 2 miles left.

" Worcester originally had 62 miles of cement-covered sheet-iron pipe, but found as it became old that it cost a great deal for repairing leaks and for damage by washouts. It has already dug up and replaced 53 miles of it with cast iron, and expects to tear out and replace all there is now remaining during the coming year.

" Manchester, N. H., put down many miles of the sheet-iron pipe at the original construction of its works twenty-two years ago, but has abandoned its use and lays only cast iron; and during the year past dug out nearly two miles of its 4-inch, 6-inch, and 8-inch, replacing the same with cast iron.

" The fire which nearly wiped out the business center of Spencer, Mass., two year ago, gained its destructive headway by reason of the water being shut off for a few hours to repair a rust crack in a cemented main.

" In Rome, N. Y., about a year and a half ago, the bursting of a

cement pipe main during a fire led to a property loss of upward of two hundred thousand dollars.

" In Somerville, Mass., the experience with the cement pipe for street mains was wholly unsatisfactory after the pipes became old, and the sudden development of a cold water geyser in the public street has, on one occasion at least, involved the city in a heavy claim for damages. At Lynn one similar burst of a cement pipe main is stated to have cost the city about ten thousand dollars for the broken windows and the general deluge, and they long since abandoned laying more.

" Coming nearer home and to water from the Middlesex Fells region, the same as our own:

" In Malden, the many breaks in the cement pipe were a serious obstacle to increasing the pressure on the pipes from the new distributing reservoir. The laying of cement pipe has been abandoned, and much of that originally laid has been dug up and replaced by cast iron.

" In Melrose they still lay some cement pipe, mostly in districts where pressure is low, but are laying cast iron for the important lines, and a member of their water board says they will probably soon lay cast iron exclusively.

" Medford abandoned cement pipe several years ago, and lays cast iron now exclusively. Medford had about ninety breaks on cement mains in 1893, and keeps a man at the shop day and night ready for repairs with a horse harnessed with a ' fire department quick-hitch ' for the cement pipe repair wagon. During the past year they tore up and relaid with cast iron about seven miles of cement pipe, but a part of this was done to obtained increased size in mains.

" Many additional examples could be quoted to show that Winchester in changing from cemented sheet iron to cast iron is very near to the conservative end of a very long procession.

"*Fourth.* Cement pipe even when filled with water is often struck by lightning and thereby ruined. Last year in our neighboring town of Arlington, a long piece of cement pipe was shattered from this cause and replaced by cast iron. Woburn has had similar disasters from cement-lined pipe struck by lightning. Lynn has suffered repeatedly from this cause, and Fitchburg has had similar experiences, and many other towns have had like accidents, sometimes ⅓ mile of pipe being instantly ruined. In Winchester, in 1880, about 400 feet of the 6-inch high-service main was ruined from this cause and replaced.

" On the whole, Winchester has simply had unusually good luck in this matter of lightning damage.

"*Fifth.* Cast-iron pipe can safely be laid or repaired or cut into in freezing weather. Cemented pipe is endangered by frost spoil-

ing the set of the mortar exposed thereto, and, therefore, cannot safely be laid so early in spring or so late in the fall as cast iron.

"*Sixth.* Cast-iron pipe runs less risk of suffering from the accident of a careless workman. Each 12-foot piece having been tested under heavy hydraulic pressure at the factory, the joints are almost the only parts where leaks can occur from careless treatment, as by not filling or driving the lead joint properly. In a cement pipe, every square inch of surface is susceptible to injury from careless covering or lining, or from a lump of poor mortar. In soft ground, or ground disturbed by sewer work, cemented pipe will not resist straining so well as cast iron.

"*Seventh.* Cement-lined pipe has one great advantage over cast iron, namely, tubercles do not form on its interior surface. This remains clean and smooth and free from obstruction to the flow, even after twenty years of service.

"With cast iron, even though tar-coated, oxide of iron does commonly collect, the rate depending upon the quality of the water and the excellence of the tar-coating. Ultimately, perhaps in twenty-five to fifty years, this coating of hydrated oxide of iron may almost completely cover the interior surface; but even then with a 6-inch pipe there will probably be a 4-inch hole remaining open. Moreover, there is a device already in use in several cities having very old cast-iron pipe laid before the days of tar-coating, by which the tubercles can be scraped out of a pipe without taking it up. This device consists of a scraper actuated by the water pressure."

Early in the present year, 1908, to bring down to date the opinions formed in the various towns referred to in the above citations, the writer sent one of his assistants to interview the superintendents of water works in a number of our New England cities using pipe of this character, and to look up such references on the subject as he might be able to find. The result of these inquiries, together with some material collected in Lynn by Mr. E. V. French,* kindly placed at the disposal of the writer, and some inquiries and observations of the writer, are shown in the following memoranda:

ATTLEBORO, MASS. (Information from Mr. Geo. H. Snell, superintendent.)

In 1905 Attleboro had a population of 12 702. The works were constructed in 1873, cement-lined pipe being used for the mains. The further use of this pipe was stopped in 1880, and the

* Vice-President of the Arkwright Insurance Company, and a member of this Association.

work of replacing it with cast-iron was commenced in 1898. At the present time there is no cement-lined pipe in use. In 1880, 16 miles of the cement-lined pipe had been laid. The superintendent states that the use of this pipe was stopped because of the trouble in making connections and the liability of breaks at these points. When the system was first in use it was customary, in case of fire, to shut off all but the affected district, this being done because of fear of breaks due to the increased pressure from the pumps, the normal pressure of 65 pounds being raised to about 100 during fires. No figures are obtainable regarding the cost of repairs of this old pipe, as it was done by plumbers under contract. It is said that the number of breaks was large, the cost of repairs, involving the substitution of a piece of cast-iron pipe, running as high as $15 for an ordinary break.

The superintendent remembers trouble from lightning previous to 1881, when about seventy-five feet of main pipe was destroyed. The town is not provided with a system of sewerage, so that there has been no serious trouble from digging up of the streets.

BEVERLY, MASS. (Information taken from the published reports of the Water Board.)

In 1905 Beverly had a population of 15 223. The works were originally installed in 1869, water being obtained from Salem. In 1885 the works were enlarged, an independent supply was obtained at an increased pressure of about ten pounds. The effect of this pressure on the pipe is very noticeable, the average number of breaks from 1879 to 1886 being 63 per year. In 1887 the number of breaks was 249. The use of cement-lined pipe was practically abandoned in 1894, and in 1897 and following years the annual reports have clauses recommending the replacement of the cement-lined pipe with cast-iron on account of the poor condition of the old pipe.

Effect of Lightning. On August 10, 1878, 357 feet of 4-inch pipe was destroyed. On October 1, 1883, 600 feet of 4-inch pipe was destroyed. On July 23, 1888, one stroke of lightning caused three breaks. On June 17, 1892, one stroke caused several breaks and required replacement of 108 feet of pipe. In 1901, 2 000 feet were badly shaken by lightning and had to be replaced.

The size of pipe varies from 4 inches to 18 inches in diameter. Average pressure, 72 pounds. Average age of pipe, thirty-four years.

Following is a table of statistics relating to the leaks and cost of repairs:

Year.	No. of Leaks.	Miles of Cement-Lined Pipe.	Miles of Cast-Iron Pipe.	Total Cost of Repairs.	Cost of Repairs per Mile Cement Lined Pipe.
1888.....	206	49.0	1.1	.....	.....
1889.....	103	....	...	.....	.....
1890.....	121	50.0	1.4	.....	.....
1891.....	194	50.3	2.4	$1 658.	$33.10
1892.....	271	49.5	3.9	2 179.	44.00
1893.....	149	49.5	4.9	1 507.	30.50
1894.....	148	49.6	5.3	1 522.	30.70
1895.....	146	48.2	7.2	1 577.	32.80
1896.....	...	...	...	.....	.....
1897.....	74	47.3	9.5	2 875.	60.80
1898.....	152	46.0	19.7	6 250.	134.50
1899.....	160	46.0	11.3	2 193.	47.75*
1900.....	98	45.7	12.1	1 358.	29.80
1901.....	198	44.0	13.8	2 882.	65.50
1902.....	118	42.5	15.4	1 597.	37.60
1903.....	149	41.8	16.4	.....	.....
1904.....	177	38.4	20.7	2 264.	49.00
1905.....	99	34.7	27.6	1 731.	50.00
1906.....	107	32.4	30.7	1 890.	58.40
		Average,		$2 249.	$50.45

Brockton and Whitman, Mass. (Information from superintendent of water works Horace Kingman, and city engineers Charles R. Felton, of Brockton, and Julius C. Gilbert, of Whitman.)

In 1905 Brockton had a population of 47 494, and Whitman of 6 521.

The only use of cement-lined pipe in Brockton is for a main connecting a reservoir with the city. This main consists of 20-inch and 24-inch pipe, and is about 15 000 feet long; half of it is through a country district, and the remainder through one of the streets on the outskirts of the city. This latter part of the main has numerous connections. The pipe was laid in 1880 and was made by dipping the wrought-iron shell in hot asphaltum and afterwards rolled in sand and cement before putting on the final coating. The main is under a varying pressure, which averages about 50 pounds.

* Figures previous to this date in some cases contain items other than those relating to repairs of leaks.

The superintendent states that no trouble whatever has been experienced with this pipe during the twenty-eight years of its existence.

In the town of Whitman there are about 12 miles of cement-lined pipe, and 12 miles of cast-iron. The works were installed in 1882–3, at which time cement-lined pipe was used for the mains. For all extensions since that time cast iron has been used. The superintendent states that the particular reason for using cast-iron pipe was that they had no appliances for making the cement-lined, and cast-iron pipe lends itself more readily to laying and to making connections. He says that practically no trouble has been experienced with the old cement-lined pipe, which has now been in use twenty-six years. The average pressure on the main is 65 pounds. The town is without a sewerage system and so there has been in the past very little digging up of the streets.

CONCORD, MASS. Population, 1905, 5 241.

The original works, consisting of a 10-inch supply main leading from Sandy Pond in the town of Lincoln to the town of Concord, and distribution pipe system from 3 inches to 8 inches in diameter, were built of wrought-iron cement-lined pipe in the year 1874. The pipe was of the socket type, known as the Knight-Bailey patent, but sleeves were also used outside of the socket joints in wet places and on curves. Branches were of cast iron. The wrought iron used in the shell was of the following gages:

Diameter, Inches.	Birmingham Gage.	Thickness, Inches.
3	23	0.025
4	22	0.028
6	20	0.035
8	19	0.042
10	17	0.058

The pipe was lined with 1 : 1 Rosendale cement mortar, and covered with a 1 : 2 mixture of the same. In wet trench the covering mortar was mixed in the proportion of 1 of cement to 1 of sand, or even richer. The joints were made with pure cement. The factor of safety upon the pipe system as a whole was supposed to be approximately 5, based upon an average head of 100 feet, or 43 pounds pressure per square inch, and a maximum head of 110 feet. The pipe was laid under contract by Ferris & Halliday, and

the contract cost thereof, as taken from the notes of the engineer for the town, Mr. William Wheeler, member of this Association, was as follows:

10-inch,	13 004.5	feet at	$1.57 =	$20 450.
8 „	996.5	„ „	1.22 =	1 215.
6 „	6 090	„ „	1.02 =	6 210.
4 „	10 375	„ „	0.76 =	7 890.
3 „	281	„ „	0.69 =	194.
Total,	30 747	feet,		$35 959.*

Mr. Wheeler estimated the cost of substituting cast-iron pipe for wrought-iron cement-lined pipe in this work at $41 100, cast-iron pipe being quoted in the year 1874 at $45 per ton, and having been quoted in the previous year at $65 per ton. The probable saving effected by the use of wrought-iron cement-lined pipe instead of cast-iron pipe at that time (1874) amounted, therefore, to a sum of $5 141, and it is interesting to note that subsequent developments have certainly justified the engineer's decision at that time on the score of economy to make use of wrought-iron cement-lined pipe in preference to cast iron for the following reasons:

The accumulation upon the saving of $5 141 compounded semi-annually at 6 per cent. (the rate of interest carried by notes or bonds issued by the town to cover the loan made for the water works) amounts to a present sum of approximately $19 500, and if we add to this amount 45 per cent. of $41 100 (the estimated cost of the cast-iron pipe system) to cover depreciation, based upon an annual allowance of $\frac{1}{2}$ per cent. compounded annually at a rate of 5 per cent., and amounting approximately to $18 500, we have a total sum of approximately $38 400, which would more than cover the reproduction cost to date of a new cast-iron pipe line of even greater strength than that of the old wrought-iron cement-lined pipe. Had the price of cast-iron pipe been $25 per ton, the average ruling present-day price of cast-iron pipe, instead of $45 per ton, as it was at that time, the conditions would not have appeared so favorable.

It is worthy of note that the wrought-iron cement-lined pipe is still in use and that a high-service fire protection system is now being installed which will increase the pressure upon the greater

* Excluding 306 feet of 12-inch conduit in Sandy Pond.

CONCORD WATER WORKS.

Year.	Miles of Pipe, End of Year. Wrought Iron and Cement.	Cast Iron and Unlined Wrought Iron.	Total.	No. of Leaks on Cement-Lined Pipe.**	Cost of Repairs on C. L. Pipe.	No. of Leaks per Mile of C. L. Pipe.	Cost of Repairs per Mile of C. L. Pipe.
1874	5.58	0.63*	6.51	....	....§	....	....
1875	6.91	1.03*	7.94	....	....§	....	....
1876	6.91	1.03*	7.94	....	....§	....	....
1877	8.43	1.10*	9.53	....	....§	....	....
1878	9.79	0.60*	10.39	....	$18.25§	....	$1.86
1879	9.90	0.77*	10.67	....	51.05§	....	5.16
1880	9.90	0.99*	10.89	....	76.65	....	7.75
1881	9.90	0.99*	10.89	....	102.25	....	10.33
1882	9.90	1.13*	11.03	....	22.80	....	2.30
1883	16.65	1.15*	17.80	....	33.96	....	2.04
1884	19.71	0.97*	20.68	....	29.88	....	1.52
1885	19.71	1.10*	20.81	....	145.57	....	....
1886	19.71	1.11*	20.82	....	121.36†	....	....
1887	19.71	1.27	21.98	....	225.03†	....	....
1888	20.96	1.49	22.47	....	....	....	....
1889	20.96	2.42	23.38	....	No leaks	....	....
1890	20.96	2.59	23.55	....	No leaks	....	....
1891	20.96	3.14	24.10	....	....‡	....	....
1892	20.96	3.41	24.37	....	....‡	....	....
1893	20.96	3.52	24.48	....	....‡	....	....
1894	20.98	4.40	25.38	....	....‡	....	....
1895	20.98	5.36	26.34	....	....‡	....	....
1896	20.98	5.77	26.75	....	....‡	....	....
1897	20.98	6.12	27.10	....	....‡	....	....
1898	20.88	6.80	27.68	....	....‡	....	....
1899	20.88	7.03	27.91	....	....‡	....	....
1900	20.66	7.62	28.28	18	....‡	0.87	....
1901	20.65	8.58	29.23	19	....‡	0.87	....
1902	20.65	8.73	29.38	13	....‡	0.63	....
1903	20.62	10.96	31.58	14	....‡	0.68	....
1904	20.62	11.43	32.05	18	....‡	0.87	....
1905	....	....	....	20	....	....	....
1906	20.40	12.19	32.59	17	....‡	0.83	....
1907	20.35	12.40	32.75	10	....‡	0.49	....

*Mostly 1-inch to 2-inch tarred and enameled wrought-iron pipe. The first cast-iron mains were laid in 1880.

** No record from 1874 to 1899 inclusive.

† Includes renewals of services in 1887; whole amount devoted to this purpose.

‡ Data for this period cannot be separated from other items.

§ Repairs made by contractor.

part of these mains from 43 pounds per square inch to approximately 100 pounds. Undoubtedly some replacement of pipe will be required, but time alone can develop the extent of the replacement which will be necessary.

The laying of wrought-iron cement-lined pipe in Concord was abandoned in the year 1888.

Up to the present time repairs upon wrought-iron cement-lined pipe have not been excessive in cost, but they may prove so hereafter under the greater pressure.

The record of leaks and cost of repairs upon the cement-lined pipe has, unfortunately, not been kept separate in bygone years from that upon cast-iron pipe, or, indeed, from repairs upon other parts of the water-works plant. Such information as the writer has been able to gather, with the assistance of the present superintendent, Mr. Leonard C. Robinson, is contained in the tabulation on page 20.

CONCORD, N. H. (Information from Superintendent Percy R. Sanders.)

In 1900 Concord had a population of 19 632; a system of water works was installed in 1872, cement-lined main pipe being used. In 1883 a main from the source of supply to the city was laid, and in 1887 an extension to the village of Penacook was made. This completed the use of cement-lined pipe, all extensions since having been made with cast iron.

In 1898 the work of replacing the pipe laid in 1872 was commenced and is still in progress, as there remain about 14 miles of the 28 miles in existence in 1887. The pipe laid in 1883 and 1887 is still in use and, according to the superintendent, is in excellent condition, very little money having been expended upon it in repairs. The old pipe is being taken out because of the number of breaks caused by rust. There has been some trouble from lightning, in one case 388 feet of pipe being destroyed by this cause. The pressure on the pipe varies from 45 to 75 pounds, and some of the pipe is between the pumps and the reservoir. The sizes of pipe vary from 4 inches to 20 inches in diameter. Leaks have been recorded as follows:

Year.	Cost of Repairs.	No. Miles Cement-Lined Pipe.*	Cost of Repairs per Mile.
1900.....	$660.	29	$22.70
1901.....	485.	27	18.00
1902.....	432.	25	17.20
1903.....	309.	23	13.40
1904.....	496.	21	23.60
1905.....	237.	20	11.80
1906.....	260.	18	14.40

DANVERS, MASS. (Letter from Superintendent Henry Newhall.)

DANVERS, MASS., August 24, 1908.

Mr. L. METCALF:

Dear Sir, — It seems impossible that your letter was dated July 21 and is unanswered. Besides my regular work, I have had 14 000 feet of 18-inch, 8 000 feet of 12-inch, and 7 000 feet of 6- and 4-inch *cast iron* to attend to, and to-day is the first day we have not worked. I hardly see how I could write anything for your meeting; my experience on cement-lined pipe has been largely in repairing an old pipe that was mostly *sand.* Mr. Blackmer has had experience in making and laying with both kinds, although the ancient kind was under low pressure. I will send you a pamphlet report of our committee. We lost the vote and so had to use cast iron. My opinion in brief *in re* cement-lined pipe is, that the Phipps double pipe is the best water pipe ever used, provided it can be made to use lead joints. We have used the 4-inch in a small degree, which worked satisfactorily, but when it came to finding out if an 18-inch could be made without the casting costing too much, and if it would stand the heavy calking necessary when empty, we were unable to do so. My experience has been unfavorable to cement joints made by regular water-works employees; in fact, in those made by men that called themselves experts, we have had *trouble* the *first year.* This seems to be the experience of a lot of water works men to whom I wrote. We wound them and in a few years they rot off. I now put on a split sleeve on all but the 4-inch, i. e., on the 8-inch and 12-inch, as the cheapest way to mend. You will see by the report I mail that we have only a little over a mile of the modern cement-lined pipe; most of the rest was laid or made thirty odd years ago. Our main is 12-inch, 3 miles long under 75 average pressure. We have had but one burst for ten years, but any quantity of joints leak. That is not so bad for a pipe where one-half sand was allowed in lining

* Includes the Penacook extension of about 4 miles, and a low service main of about 2 miles, which have as yet caused no trouble.

and a "cement mortar" for outside. The smaller sizes do not make so good a showing; from the appearance of the lining, I am inclined to think that a great deal of the trouble was due to imperfect mixing by hand; while some you can crumble in your hand perhaps a few inches away it is as hard as a rock. I didn't mean to write you but a few lines, but I am very much interested in cement-lined pipe, although I see no prospect in using it at present. If you think I could give you any information in the form of answering questions, I should be only too happy to do so. I do not belong to the Association as unfortunately I am too deaf to hear the proceedings.

Yours truly,

(Signed) HENRY NEWHALL.

Under date of May 22, 1907, a committee appointed by the town of Danvers to "look into the advisability of establishing a plant for the town to manufacture cement pipe to be used by the water department," presented an interesting report in which it discussed the relative cost of wrought-iron cement-lined and cast-iron pipe and concluded after careful consideration that it was "advisable to establish a plant for the town to manufacture cement pipe to be used by the water department."

Without in any way wishing to criticise the action of the committee, particularly as the local situation has not been examined by him, the writer desires to call attention to the fact that the committee based its findings upon cast-iron pipe at $30 per ton, and used in its computations a weight of cast-iron pipe which would give a strength far in excess of that of the wrought-iron cement-lined pipe with which comparison was being made. Inasmuch as, in the judgment of the writer, to make the computations strictly comparable, a considerably lower price for cast iron should have been used, since the ruling price of cast-iron pipe during the last twenty-five years has been approximately $25 per ton, as will appear from later discussion of this subject in this paper, and as a much lighter cast-iron pipe would have given equal strength and reliability with the wrought-iron cement-lined pipe, and as no allowance was made for the fixed charges resulting from the construction of a plant for the manufacture of wrought-iron cement-lined pipe, the comparison submitted by the committee does not appear to the writer to be quite fair, — particularly when the

difficulty of securing uniformly good work and reliability of the cement-lined pipe in service, as compared with cast-iron pipe, is given due weight.

GLOUCESTER, MASS. (Information from Herman W. Spooner, Engineer.)

The Gloucester Water Supply Company was granted charter in 1881, which was transferred to Mr. George H. Norman in 1884. The plant was put into operation in the fall of 1884. In the year 1895 the plant was taken by the city of Gloucester. At that time the entire pipe system, amounting to approximately 23.5 miles, was of wrought-iron cement-lined pipe. Since that time nothing but cast-iron pipe has been laid, and approximately 4½ miles of the wrought-iron cement-lined pipe has been replaced with cast-iron pipe. At the present time the system comprises approximately 64 miles of pipe, of which approximately 19 miles are wrought-iron cement-lined pipe.

The use of wrought-iron cement-lined pipe was given up on account of its unreliability and the excessive cost of repairs. The majority of leaks were caused by rupture at the joints, though some were due to careless work in neighboring excavations and a few probably to electrolytic action. Thus, in the year 1906, out of 44 leaks and breaks in the cement-lined pipe, 23 were leaks in service pipes, 3 leaks or breaks in the mains, the latter and the leaks in the service pipe being caused by electrolysis.

On several occasions the cement-lined pipe has been injured by lightning. Thus, on September 6, 1896, 17 leaks upon one street were caused by lightning during a severe shower. It was then found necessary to shut off nearly three quarters of a mile of pipe, as the leaks appeared at regular intervals throughout the entire line along Mount Pleasant Avenue from Highland to East Main streets. Other instances of from 3 to 7 leaks have been noticed since that time, though of considerably less serious nature.

GREENSBURG, PENN. The original water works of the Westmoreland Water Company supplying Greensburg and a chain of adjacent towns lying about thirty miles east of Pittsburg, were

built in the years 1888 and 1889, using cement-lined pipe. The amount and prices paid under contract for furnishing pipe, hauling, ditching and backfilling, making joints, etc., were as follows:

Diameter.	Length.	Cost per Foot.
16-inch	6 602 feet	$1.80 (very light)
14 „	49 675 „	1.85
12 „	34 863 „	1.53
10 „	22 438 „	1.17
8 „	16 490 „	0.92
6 „	20 386 „	0.66
4 „	14 358 „	0.51
	Total, 164 812 feet = 31.21 miles	

With regard to the pipe system, the manager and treasurer of the Westmoreland Water Company, Mr. Murray Forbes, says:

Data on Material in Pipe.

"All the above pipe was known as 'Phipps,' viz., an excellent grade of tough wrought iron lined and covered with an excellent quality of neat cement. On the outside a light wrought-iron jacket was placed for protection during transportation and handling.

General.

"The characteristic territory through which this piping was laid is hilly, with a maximum head of about 375 feet. At several points the line passed marshy ground. On beginning operations there was an excessive leakage, which was subsequently hunted up, very carefully repaired, and upon test the pipe was found tight.

"The leakage was confined to:

"1. Joints on straight pipe.

"2. Specials.

"1. The defective joints were invariably in certain sections, generally in low, wet, or marshy ground. In these places almost every joint was defective and apparently due to:

"*A.* Careless and defective joint making.

"*B.* Joint cement having been wet.

"*C.* Boozing of the joint makers.

"2. The 'Specials' were poorly and inadequately made, and many burst and leaked more or less, and practically all had to be removed and replaced with cast iron.

Experience.

" After the defects were made good in a systematic and thorough manner, this pipe has been admirable, and we have had little or no trouble.

" As a distribution pipe, there are several objectionable points.

" 1. The tapping must be done by a saddle, which runs the expense up, and while we have possibly 5 000 taps on this pipe and have had very little trouble, honest care must be used in making them or there would be.

" 2. The pipe is easily punctured, and in our towns of to-day where sewers, gas pipes, and telephone conduits are continually being dug over and across this pipe, a pick will go clean through it.

" As a supply pipe, I don't believe it has a superior. We have had it in service nineteen and twenty years (at our Derry, Penn., system, twenty-one years) and it is as clean on the inside as it was the day it was laid."

In further comment upon his experience with this pipe line so far as leakage goes, Mr. Forbes writes:

" I took a great deal of pleasure and interest in reading over your paper on ' Wrought-Iron Cement-Lined Pipe,' and think it admirable, and I agree with your conclusions, viz.,

" Disadvantageous for distribution systems.

" Satisfactory for supply systems when carefully and honestly made and laid.

" From 1889 to 1907 inclusive, we have repaired 1 615 leaks on cement-lined pipe. This work can be divided into two classes:

" Leaks hunted for, due to bad workmanship in construction, from 1889 to 1894	1 506
" Leaks breaking out from 1894 to 1907	109

" To further subdivide this latter period:

" Leaks, 1894 to 1898	67.	Average per year	13.4
„ 1899 „ 1907	42.	„ „ „	4.7

" In other words, after the cement-lined mains were put in tight and serviceable condition, although about twelve years old (laid in 1888), they held pretty well. However, I am only giving you these figures as interesting, for if I can present a paper I'll use them, but if I find it will be impossible for me to be present, I'll turn them over to you.

" I notice one point in J. W. Ledoux's letter of July 22, viz.,

" 'The Westmoreland Water Company's system is one of the first built and one in which the pressures are much greater in places than the pipe should have been made to stand according to the standard of manufacture.'

" This may be, to some extent, true, but the point of greatest pressure on the Immel-Dry Ridge 14-inch line was laid in August, 1888, and put in service in December, 1888, and has been so ever since. We had a great many leaks in this place, but finally got it all fixed up about 1894, since which time we have had almost no trouble at all.

" To my mind, this Immel-Dry Ridge 14-inch line is holding splendidly. In 1907 we cut in a 14-inch by 4-inch tee in the district of heavy pressure referred to, and the pipe was in fine condition. It may be, that in the next ten years we'll have trouble.

" We have other points where the pressure is heavy, but the figures for the last nine years don't indicate trouble so far. Less than five leaks a year on about thirty-nine miles under heavy head, in places, is not conclusive."

LEE, MASS. (Information obtained by Mr. A. A. Fobes from Dr. F. K. Chaffee, superintendent.)

The works were built about 1883 and comprised from 8 to 10 miles of wrought-iron cement-lined pipe. Last year there were three leaks upon the pipe system, but the general average is approximately five or six leaks per year. The cost of making repairs is approximately $25 to $30 per leak. This is larger than it might be as they repair by inserting a piece of cast-iron pipe and using two cast-iron sleeves. They do this as none of the present management know how to make cement pipe. The chief cause of trouble has been the rusting of the steel.

Some trouble has been experienced from lightning. In 1892 lightning struck the pipe on the top of one hill and came out on the top of another, about two thousand feet away; the pipe between these two points seems to have been damaged, as several leaks occurred on that section, covering in all a period of twelve years.

The greatest pressure on the mains is approximately ninety pounds.

The system is in good shape and is considered a valuable asset, but all new pipe laid is cast iron, as no one in Lee knows how to lay the cement-lined pipe, and they have no machine for making it.

LYNN, MASS. (Information from Superintendent D. A. Sutherland to Mr. E. V. French.*)

Extract from letter of Mr. Sutherland to Mr. French, dated February 8, 1908.

"I enclose a table showing the amount of cement-lined pipe in the system in the years 1875 to 1908 and the number of breaks each year. We have also inquired of the foremen in regard to

Year.	Length of Cement-lined Pipe. Miles.	Feet.	Leaks.	No. of Failures per Mile per Year.
1875.....	46	3 063	130 (34 from frost)	2.82
1876.....	46	4 287	94 (1 burst caused by sewer)	2.04
1877.....	47	1 049	79	1.68
1878.....	49	1 503	79	1.61
1879.....	49	1 503	102	2.08
1880.....	52	1 433	121	2.13
1881.....	56	849	104 (on pipe of all sizes)	1.85
1882.....	60	809	119 " " " " "	1.98
1883.....	62	2 144	92	1.48
1884.....	63	2 140	84	1.33
1885.....	63	3 474	105	1.66
1886.....	63	3 609	107	1.69
1887.....	63	3 609	99	1.57
1888.....	63	3 609	79	1.25
1889.....	63	1 533	106	1.68
1890.....	61	3 504	136	2.22
1891.....	60	2 119	114	1.90
1892.....	59	3 007	132	2.23
1893.....	57	2 755	119	2.08
1894.....	56	2 983	99	1.76
1895.....	54	5 271	167	3.09
1896.....	53	4 714	147	2.77
1897.....	51	4 590	102	2.00
1898.....	50	4 523	115	2.30
1899.....	48	2 139	142	2.95
1900.....	46	5 072	...	?
1901.....	44	4 358	82	1.86
1902.....	42	879	82	1.95
1903.....	41	2 903	94	2.29
1904.....	37	2 903	96	2.59
1905.....	34	3 217	113	3.32
1906.....	32	253	91	2.84
1907.....	28	1 721	91	3.25
			Average,	2.07

* Published through the courtesy of Mr. French, member Lynn Water Board, Vice-President Arkwright, Mutual Fire Insurance Company, and member New England Water Works Association.

the cause of the breaks of the cement-lined pipe, and their replies as to the cause were the same as what we told you Saturday night.

"I am also enclosing a clipping from the 1885 report which may be of some interest to you in regard to the cause of the pipe giving out. We have had no trouble with the large main from the ponds to the pumping station except a few leaking joints on the 20-inch pipe from the pumping station to the reservoir; and one burst on the 22-inch pipe from Birch Pond to the pumping station. The latter was supposed to be caused by some repairs being made on one of the gates in the gatehouse at that time. Since that time we have had no further trouble from this pipe. I would seriously recommend relaying the 20-inch pipe from the pumping station to the reservoir as soon as possible, as any trouble on this main might cripple our water supply to the city."

The clipping states that a number of leaks were caused by pick holes made during excavation for sewers, but that the worst bursts have been where the pipe has been damaged in previous years by excavation and covered up without giving notice of injury. In other cases the fault is from carelessness in laying the pipe, either not using a sufficient quantity of cement in covering the pipe or injuring cement while green in backfilling trenches.

The inner layer of cement was usually about one-half inch thick; the outer layer varying from one-half inch to three-quarters inch except at the bottom, where a sort of base was made. The pipe was received with the inner coating in place, was laid in a bed of cement in the trench, and then the outer cement covering put on by hand with rubber gloves.

In some places the covering is a good deal thicker than in others. In all cases Rosendale cement was used.

The cause of bursts is some flaw in the cement coating which allows the iron to gradually rust. In some cases the break is a small roundish hole; in others, a longitudinal crack. Where cracks occur, they are almost always longitudinal and seldom transverse to the pipe.

The joints were made by butting two lengths of pipe together, wrapping with a sheet of rubber, and winding the rubber with rope; then the whole was smeared with the Rosendale cement and a sheet-metal sleeve pushed over the joint outside the rope, and finally the whole covered with cement. The joints seldom give trouble and seem to be stronger than the main pipe.

Service taps are made by removing a little cement and punching out a hole in the iron, then the connection is soldered, using a soldering iron. The hole is then finally sealed with cement. These taps do not give trouble and do not seem to at all weaken the pipe.

The pipe laid in later years, 1881 to 1883, was covered with a black asphalt paint, and this seemed to considerably retard rust and make the pipe more durable.

The experience at Lynn was that for the first fifteen to thirty years there was not much trouble from bursts, then the pipe began to go and sections would frequently burst at so many places within a few years that they had to be removed as promptly as possible. It is said that pipe was first laid by contract and was not as well done as that put in later by the city, and consequently gave more trouble.

There is a 16-inch pipe from the pumping station to the reservoir which it is thought has never burst, to the best of the recollection of Mr. Sutherland and his son. The 22-inch from Birch, and the 18-inch from Breed, which are under light pressure, have never burst.

When there was a good deal of the pipe in use, breaks frequently occurred during fires. They are not now so common as the cement-lined pipe has been removed largely from the business sections, where most of the serious fires occur.

In the city streets the digging for sewers and other purposes does not disturb the cement pipes and cause breaks. Wherever cement was put on in a thorough manner, it is found, on knocking it off, that the pipe underneath is bright, with a bluish tinge, seemingly in just as good condition as when it was put in.

Test of 16-inch and 4-inch Cement-Lined Pipe, from Lynn, Mass., Water Works.

Specimens of the plate and longitudinal joints were secured and tested in a Riehle machine at the Massachusetts Institute of Technology, through the kindness of Professor Miller, and with the assistance of C. W. Mowry. These samples were more or less pitted and weakened on the surface by rust caused by exposure to weather, with the outside coat of cement removed.

The 16-inch pipe was laid in 1870 and remained in service until last fall. The shell is said to be sheet iron. It is riveted longitudinally by a single riveted lap joint. Each length of pipe consisted of 3-foot sections riveted together by single riveted lap joints. The rivets were iron and were riveted cold. The joints between lengths were made as described above.

The 4-inch pipe was probably laid about 1881–1883. The shell is said to be sheet iron. It is riveted longitudinally by a single riveted lap joint. The rivets were iron and were riveted cold. The joints between lengths were made in the same manner as in the case of the 16-inch pipe.

	16-Inch.	4-Inch.
Diameter of shell	17½ inches	4¾ inches
Thickness of plate	$\frac{5}{64}$ "	$\frac{1}{32}$ "
Size of rivets	¼ " (diam.)	¼ " (diam.)
Pitch of rivets in longitudinal joint,	1 "	1 "
Pitch of rivets in ring seam	4½ "	.....
Lap	1⅛ "	⅞ "

RESULT OF TEST, 16-INCH PIPE.

Tensile Strength per Inch of Width of Plate.

First specimen	3 159 pounds
Second "	2 567 "
Third "	3 098 "
Average	2 941 "

Strength of Longitudinal Joint per Inch of Width of Plate.

First specimen	2 057 pounds
Second "	1 920 "
Third "	2 060 "
Average	2 012 "

Load on pipe per inch of length, assuming 50 pounds steady water pressure on the interior of the iron pipe. No allowance was made for any strength in the cement lining or coating.

$$\text{Load} = \text{Pressure} \times \text{radius of pipe.}$$
$$= 50 \times 8.75 = 437.5 \text{ pounds.}$$

Efficiency of Joint.

$$\text{Efficiency} = \frac{\text{Strength of joint}}{\text{Strength of plate}} = \frac{2\,012}{2\,941} = 0.68$$
$$= 68 \text{ per cent.}$$

Factor of Safety.

$$\text{Factor of safety} = \frac{\text{Strength of joint}}{\text{Load on pipe}} = \frac{2\,012}{437.5} = 4.6.$$

RESULT OF TEST, 4-INCH PIPE.

Tensile Strength per Inch of Width of Plate.

First specimen	781	pounds
Second "	888	"
Third "	863	"
Average	844	"

Strength of Longitudinal Joint per Inch of Width of Plate.

First specimen	833	pounds
Second "	830	"
Average	831	"

Load on pipe per inch of length, assuming 50 pounds steady water pressure on the interior of the iron pipe. No allowance was made for any strength in the cement lining or coating.

$$\text{Load} = \text{Pressure} \times \text{radius of pipe.}$$
$$= 50 \times 2.375 = 119 \text{ pounds.}$$

Efficiency of Joint.

$$\text{Efficiency} = \frac{\text{Strength of plate}}{\text{Strength of joint}} = \frac{831}{844} = .98.$$
$$= 98 \text{ per cent.}$$

Factor of Safety.

$$\text{Factor of safety} = \frac{\text{Strength of joint}}{\text{Load on pipe}} = \frac{831}{119} = 7.$$

The failure of the plate in every instance was indicated by a sudden halt or drop in the scale beam showing practically no elasticity in the plate. In every fracture the lamina could be plainly seen and presented an appearance very much like wrought iron or mild steel.

The riveted joints failed by a bending action, which threw an eccentric load on the rivets. One side of the rivet was thus in tension and some were pulled apart, while the heads of others were pulled through the plate.

The joints between the lengths were made in such a way that

they could transmit practically no tension, and, therefore, the stress in the ring seam would be insignificant and can be neglected.

Effect of Lightning on Cement-lined Pipes at Lynn, Mass.

The following information was obtained by interviews with the superintendent and employees of the Lynn Water Works. No case of damage to cast-iron pipe caused by lightning could be recalled by them.

Chatham Street. (About 1896.) The 6-inch pipe in Chatham Street near Oakwood was struck by lightning. This caused a break necessitating the replacing of an 8-foot length of 6-inch cement-lined pipe. It was relaid cast iron.

Essex Street and Vicinity. (About 1898.) About ten years ago lightning struck in several places in the vicinity of Essex Street. The following is a list of the locations of the breaks, and damage done.

Street.	Size.	Repairs.
Liberty.....	8 inches	One 8-foot length replaced by cast iron.
Highland Square.....	8 „	One 8-foot length replaced by cast iron.
Essex (near Highland Avenue)..	8 „	One 8-foot length replaced by cast iron.
Highland Avenue (near Essex)..	4 „	One 7-foot length replaced by cast iron.
Highland Avenue (near Adams)..	4 „	Four or five 7-foot lengths replaced by cast iron.
Adams from Highland Avenue to Rockaway Street.....	6 „	About fifteen breaks were either repaired or the pipe replaced, but finally it was necessary to relay all of the cement pipe.
Rockaway, between Adams and High Rock.....	8 „	Six or seven 8-foot lengths replaced by cast iron.
High Rock, Rockaway to Acorn,	6 „	All replaced by cast iron.
Adams, corner Rockaway.....	.....	Gate broken.

Storm of June 7, 1904. In 1904 lightning caused breaks in Chatham, Ingalls, Ocean, and Acorn streets. The following list was obtained from expense slips of the department. This list shows the extent that cement-lined pipe is damaged upon being struck by lightning. One break will be repaired, the water turned on, and then the pipe will give way in some other place.

Chatham Street near Massachusetts Avenue, 6-inch pipe.

		Cost.	
June 7	Replaced one 8-foot length,	$23.18	
June 9 and 10	" " " "	17.16	
June 12	Repaired break,	10.49	
June 11 and 12	" "	11.53	
			$62.36

Ingalls Street, 6-inch pipe.

June 7	Replaced four 8-foot lengths,	$33.54	
" 8	" one " length,	14.74	
" 9	Repaired split pipe,	13.87	
" 10	Repaired break	3.12	
" 11	" "	7.00	
" 11	" "	4.29	
" 12	" "	2.34	
			78.90

Ocean Street, 6-inch pipe.

June 7	Replaced one 8-foot length,	15.41
	Total cost	$156.67

Acorn Street. There were fourteen or fifteen breaks in the 4-inch pipe. These were repaired or replaced by cast iron. The pipe was finally replaced from High Rock Street to Hollingsworth Street before it could be placed in service for any length of time. No record of these repairs could be found.

Laconia Court. (September 4, 1907.)

The damage here necessitated relaying three 7-foot lengths of 4-inch pipe.

MANCHESTER, N. H. (Information from Supt. Charles K. Walker.)

In 1900 Manchester had a population of 56 987. Water was introduced in 1872, cement-lined main pipe being used. In 1877 the further use of this pipe was abandoned and the work of replacement begun. Trouble in making repairs is given as the reason for replacing with cast iron. The last of the old pipe, with the exception of 4 miles, was removed about ten years ago. The remaining 4 miles is still in use; part of the old pipe is used as a force main and part as a main from reservoir to city. The old force main was provided with cast-iron bells and lead joints. It is under a pressure of about sixty pounds. But one accident from lightning is recorded. At the time the work of replacement began there were

about twenty-six miles of main pipe in the city. No records are kept of the cost of making repairs.

MOORESTOWN, N. J. (Information received from Mr. S. K. Robbins, secretary and treasurer of the Moorestown Water Company.)

"We have used the cement pipe exclusively since the plant was first constructed in 1888, and found it very satisfactory. Pipes laid in 1888, which were disturbed and broken recently in laying a sewer, were found in excellent condition. Of late we have had trouble in making joints, and have been compelled to wrap all joints, an expensive method, which, added to the increased cost of pipe, makes the cost of putting it in so excessive that we are seriously thinking of abandoning it and laying iron pipe hereafter.

"Another objection is lack of confidence in the ability of this pipe and joints to withstand a pressure of 100 pounds. Our system has never been subjected to this without disastrous results to joints."

PITTSFIELD, MASS. (Information from Mr. A. A. Fobes, formerly city engineer.)

The works were built in 1855 of wrought-iron cement-lined pipe, which has been entirely replaced by cast-iron pipe.

The Water Commissioners stated under date of April 13, 1868, in their annual reports:

"But it is a fact which cannot be disguised that in this town they [cement-lined pipe] have failed; and the commissioners think in consequence of the following reasons:

"The mains were not laid deep enough.

"The sleeves connecting the joints were in a great many instances very carelessly put on.

"The sections of the mains were not always put evenly together.

"The water was let into the mains before the cement had thoroughly hardened. When the pipes were first filled, the water was let on with full force, without proper precaution, and the pipes were much injured."

The general causes leading to the reconstruction of the pipe of the system with cast-iron pipe appear to have been injury due to freezing on account of the shallow depth of the trench and poor workmanship.

Some of the reports also mention injury to the mains at different times by lightning.

The static pressure upon the system averages about sixty pounds, the maximum being approximately seventy-seven pounds.

PLYMOUTH, MASS. The following information, kindly furnished the writer by the superintendent, Mr. Arthur E. Blackmer, speaks for itself. Clear, concise, and reliable, it is believed to be some of the most valuable data published thus far upon wrought-iron cement-lined pipe. Mr. Blackmer, and the previous superintendent, Mr. R. W. Bagnell, should receive full credit for it.

In substance it may be said of Plymouth's experience that they have a pipe which has given good satisfaction for many years under the conditions of their service; they are able to manufacture and lay it with some degree of economy; the maintenance of it is neither excessively expensive nor annoying; it furnishes them with clear, clean water; the friction loss in it does not appear to be excessive, and the original diameter of pipe remains substantially unchanged after years of service. Hence they naturally have no cause to regret the adoption of cement-lined pipe and have no hesitancy in continuing its use.

[COPY.]

PLYMOUTH WATER WORKS.

PLYMOUTH, MASS., February 4, 1908.

Mr. E. V. FRENCH, Boston, Mass.

Dear Sir,— Your letter of inquiry regarding cement-lined pipe at hand. I am pleased to answer your inquiries as far ar I am able. I can, perhaps, give you our experience with cement-lined pipe best by giving you a brief history of the Plymouth water works.

In 1855, when the town took over the water works from a private company, the first cement-lined pipe was laid, 10 inches in diameter, from Little South Pond (about 17 000 feet from the center of the town, and 105 feet above mean low water) to a distributing reservoir in the center of the town. The distributing pipes, of 4-inch and 6-inch sizes, laid at the same time, were also cement lined.

In 1885, the gravity supply through the above-mentioned 10-inch line proving insufficient, a pump was installed at Lout Pond, on the line of the 10-inch main, about half way between town and Little South Pond. A check valve was placed on the 10-inch line, and the pump took water from the 10-inch main above the check valve, and forced it to town below the check. During the time the pump was in operation the distributing reservoir was cut off.

A few years later a high-service reservoir, 165 feet above mean low water, was built near the pumping station, and at the same time a 16-inch cement-lined main was laid from Little South Pond to the station, and a 14-inch cement-lined main from the station to the distributing reservoir in town. At this time the town was divided into high- and low-service districts, the low-service being supplied through the 16-inch and 14-inch mains, and low-service reservoir near town; the high-service was supplied by pump, high-service reservoir, and 10-inch main; and these have been the conditions up to 1907.

The 16-inch and 14-inch mains above referred to, as far as I can ascertain, have never been repaired. The 10-inch main from high-service reservoir to town has given considerable trouble during the last five years, and we replaced it last year by a 16-inch main, of the Phipps patent, or double pipe, as it is sometimes called.

The 16-inch pipe we manufactured in our own workshop, and in the coming spring we are to manufacture some 18-inch, to lay from the pumping station to Little South Pond, replacing the 10-inch laid in 1855. We have about fifty miles of cement-lined mains now in use, some of the old style and some of the new.

Our chief, in fact our only, trouble with new style pipe thus far has been with cemented joints, and a leaky cement joint will make itself known at once.

On the new 16-inch main referred to, laid in 1907, 6 800 feet have been in use since December 15 and not a leak has thus far developed. I think you assigned the correct reason for a great deal of the trouble that has arisen through the use of the old style cement pipe, that is, defective workmanship, in both making and laying pipe, as we have found holes rusted through the iron shell, due to imperfect lining, or imperfect covering of the pipe in the trench. This refers of course to our old pipe.

With our present method of lining and covering the shell, we reduce these imperfections to a minimum, if, indeed, we do not entirely eliminate them. We of course have a great advantage over cast-iron pipe in point of cost, for the 16-inch we have just made and laid cost us $1.24 per foot to make, which I believe was a saving of about 50 per cent. over cast-iron pipe of same size last October.

There is another point which, it has always seemed to me, has not received sufficient attention in any discussion of the relative merits of cast-iron and cement-lined pipe, if I may take your time for a hypothetical discussion.

Assume a town of, say, 15 000, to have 50 miles of pipes, and assume again (which I am not ready to admit) that it is desirable to limit cement-lined pipe to 100 pounds pressure, and cast-iron to 150 pounds; would the fire protection of that town for a period

of, say, thirty years be any more efficient with its 50 pounds additional pressure on cast-iron mains and distributing pipes, more or less encrusted as they are bound to be during that period, than would the 100 pounds on the cement-lined system, which we are absolutely sure would retain its original size during the same period?* I am, of course, aware that the above question is not susceptible of exact analysis, but I believe it is a point that is frequently overlooked. With reference to further information on this subject would say that the American Pipe Manufacturing Company, of Philadelphia, own several systems in which they have cement-lined pipe, and Mr. E. H. Phipps, St. Paul Building, New York, may be able to inform you further.

Yours very truly,

A. E. BLACKMER.

MANUFACTURE AND USE OF CEMENT-LINED PIPE AT PLYMOUTH, MASS.

Plymouth is a town of about eleven thousand inhabitants and has had a water supply since 1796. Until 1855 the water was supplied to the town by a private company and the pipes they used were wooden logs with holes bored in them. In 1855 the town purchased the plant from the Aqueduct Company, and the use of cement-lined pipe in Plymouth dates from that period.

At that time about sixteen thousand feet of 10-inch pipe was laid and several thousand feet of 8-inch, 6-inch, and 4-inch pipe were laid for the distribution system. Practically all of the pipe laid at that time is still in use.

The pipe as then manufactured consisted of a sheet-iron shell about 9 feet in length, lined on the inside with about one-half inch of cement mortar, composed of cement and sand in proportions of 1 to 1. The pipe was then laid in a bed of cement mortar in the trench, ends butted together, with a steel sleeve or collar at each joint. The top and sides of the pipe were then covered with two or more inches of cement mortar, all of the same proportions as used for the lining, and a cement-mortar joint was made at each joint of the pipe.

This pipe is still in use and withstands a varying pressure in different sections, from a few pounds to about fifty pounds.

*See also concluding discussion, bearing upon coefficient discharge at Plymouth, on page 63.

In 1900, somewhat over forty miles of pipe from 4 inches to 20 inches in diameter was in use. At this time a change in the method of making the pipe was introduced, and for the past seven years all extensions have been made with a pipe manufactured in the local water-works shop, which is furnished with mechanical devices and power machinery necessary for economical manufacture.

The following description, with the accompanying photographs of the pipe as at present made, will, it is hoped, make the present method of construction clear. The pipe consists of a shell, a jacket, male and female rings, and sleeves. The shells and jackets are of soft steel and are received at the shop in flat rectangular sheets of proper size and gage. The photographs show the construction of some 18-inch pipe made at the water-works shop. For the shells of this pipe about thirty tons of steel sheets of No. 13 gage were used, at a cost of about fifty dollars per ton for the sheets.

The gage of the sheets used for the shells of pipes of different sizes varies with the size of the pipe from No. 13 gage for 18- and 16-inch pipe to No. 20 for the smallest sizes down to 4-inch.

24-inch	.....	12	gage
18 „	.....	13	„
16 „	.....	13	„
12 „	.....	15	„
10 „	.....	17	„
8 „	.....	18	„
6 „	.....	19	„
4 „	.....	20	„

The jackets are all No. 26 gage iron. Plate I, Fig. 1, shows the sheets in the shop ready to be made up into pipe, and one shell going through the punching machine.

The operation of making the pipe is as follows:

The shells are punched in the punching machine shown in the illustration; the spacing of the rivet holes is $\frac{3}{4}$ inch from center to center, the edge of the rivet hole being $\frac{5}{8}$ inch from the edge of the sheet. The sheets are then put into the rolls and given a semi-circular form, as two sheets are used for the manufacture of one shell for the 18-inch pipe. After being rolled, the shells are riveted by hand, using 816 rivets with a $3\frac{1}{2}$-pound hammer, on a stake, so-called, which is simply a bar of iron about ten feet long,

the upper surface of which is curved to approximately the same radius as the shell of the pipe which is to be riveted. The jackets are punched, rolled, and riveted in precisely the same manner as the shells and are 1½ inches larger in diameter. (Plate II, Fig. 1, shows quite clearly the riveting process.)

The rings are of cast-iron, a male ring for one end of the shell and a female ring for the other, the female ring being concave and the male ring convex, thus enabling a very tight joint to be made when the pipes are fitted together in the trench. About thirty tons of these rings were used in the manufacture of 16- and 18-inch pipe during the past year and the cost of the rings was 4 cents per pound.

The next operation, after the shells are riveted, is the fitting in of the rings, and as they are made just for a driving fit into the shell they are driven in by use of the maul. After the rings are in place the shells for the 18-inch, 16-inch, and 14-inch pipes are lined by hand, and the smaller sizes of shell from 12-inch to 4-inch are lined by means of a revolving cone. Neat Rosendale cement is used in lining. About three thousand barrels of cement have been used during the past year in the manufacture of pipe, and the cost was $1.20 per barrel, delivered at our shop.

When the shells are ready to be lined by hand they are placed horizontally on two horses. A man stands at each end of the pipe with a long-handled pallet knife, so-called, to spread the cement smoothly in the pipe. This knife is simply a flat blade about one and one-half inches wide and four inches in length, with a handle about four feet long. The cement for lining is mixed by hand in mixing boxes, and there are two men to mix for the two men who line. As the pipe lies on the horses it is lined for its whole length and half way up each side. Then the cement is allowed to set, after which the pipe is rolled over and the remaining half lined. After the cement has been smoothly spread about one-half inch thick, on the inside of the pipe, any irregularities which appear are corrected by the use of the " nigger-head," which is a stiff brush on the end of a long handle. This brush in the hands of a skillful workman can bring the interior of the cement pipes to a very smooth surface.

At this point it may be well to describe the operation of lining the smaller sizes of pipe. The shells having been punched, rolled,

FIG. 1. PUNCHING THE SHEETS.

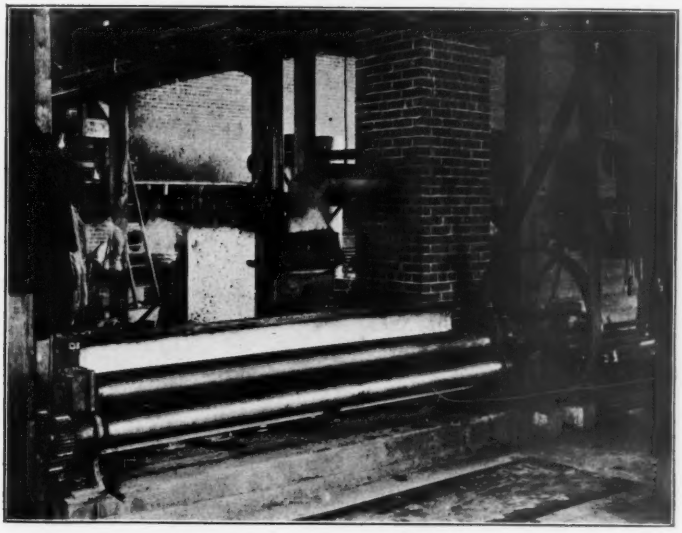

FIG. 2. ROLLS FOR SHAPING THE SHEETS.

FIG. 1. RIVETING THE PIPE.

FIG. 2. PUTTING IN CEMENT LINING.

FIG. 1. PUTTING OUTER SHELL ON PIPE; PREPARING FOR POURING GROUT.

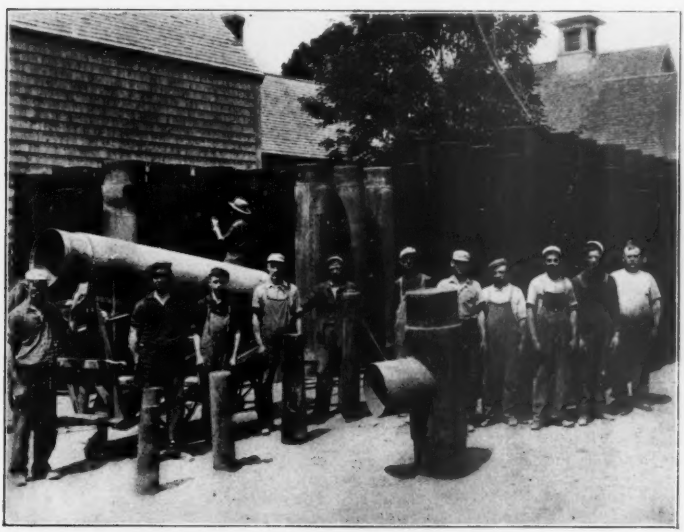

FIG. 2. STACKING AND PAINTING PIPE IN YARD.

and riveted, and rings put in in precisely the same manner as previously described, are stood upright on an elevator which descends into a pit. In this pit is the cone, so-called, which has an external diameter equal to the internal diameter of the shell when lined, — in other words, about an inch smaller in diameter than the shell — placed and held directly over it on the elevator. The cone revolves on a vertical axis and cement mixed by machinery is put in at the top of the shell as it stands on the elevator over the cone. The top of the cone, extending for a few inches into the bottom of the shell, holds the cement from falling through into the pit. The elevator holding the shell is then lowered and the cone revolving at the same time spreads the cement smoothly and uniformly on the inside of the shell.

The next operation is filling and grouting the pipe. The shells are stood on end around the edge of a platform which is about six feet above the floor. A clamp is placed around the bottom of the shell about eight inches from the lower end, and the jacket lowered from above fits into the clamp at the bottom. The jacket is kept symmetrical with the shell at the bottom by means of this clamp, and at the top by means of four wedges. The grout is merely a mixture of neat cement and water, mixed to such a consistency that it will pour readily, and is mixed by machinery in a cylindrical mixer which has four paddles. After being thoroughly mixed, the grout is poured into a metal bucket which is suspended by a chain with a wheel and is carried on a track around the platform. The grout is poured from the bucket between the shell and jacket of the pipe that has been stood around the edge of the platform. After the grout has been poured, the pipes are allowed to set twelve hours, when the cement is usually hard enough to permit of handling them. Plate III, Fig. 1, shows the method of placing the jackets and pouring the grout in the pipe. The pipes are then loaded upon a truck as shown in the photo, taken to the yard, cleaned, and painted with a coal-tar paint. After staying in the yard about two weeks they are sufficiently hard to permit of being loaded upon a wagon and carted to the trench.

Tables Nos. 1 and 2, which follow, show respectively the cost of making and laying the largest cement-lined pipes which have been made at Plymouth. Town labor, only, is used, and $2.00 is the

TABLE No. 1.

COST OF MAKING CEMENT-LINED PIPE AT PLYMOUTH, MASS.

Date.	Size Pipe, Inches.	Length Feet.	Shell.	Jacket.	Sleeve.	Rings.	Rivets.	Cement.	Paint.	Labor.	Total.	Cost per Foot.
1901	6	5 282	$650.94	$326.90	$42.25	$154.17	$25.98	$356.30	$7.14	$513.30	$2 076.98	$0.393
1901	4	2 461	186.20	104.74	12.37	43.89	12.29	162.15	1.50	281.25	804.39	0.326
1901	10	5 097	1 146.08	407.43	88.42	255.17	36.42	551.55	10.67	885.45	3 381.29	0.663
1901	6	2 007	221.34	100.71	14.02	58.18	10.03	135.41	2.66	177.09	719.44	0.358
1901	12	981	305.28	182.40	25.07	55.12	7.00	121.26	2.67	177.08	875.88	0.893
1907	16	8 109	3 722.80	852.72	337.50	1 363.35	61.90	1 728.00	15.00	1 954.42	10 035.69	1.24
1907	14	2 183	953.44	199.40	59.00	318.60	23.60	384.68	5.00	535.72	2 479.40	1.13
1907	18	7 680	3 751.60	896.40	298.80	1 460.80	119.00	1 826.00	18.00	2 457.60	10 828.20	1.41

TABLE No. 2.

COST OF LAYING CEMENT-LINED PIPE AT PLYMOUTH, MASS

Date.	Size Inches.	Length Feet.	Labor.	Branches, Gate and Hydrant.	Pipe.	Cement.	Miscellaneous.	Total.	Cost per Foot.	Remarks.
1901	12	1 292	$861.90	$418.81	$1 128.62	$70.20	$55.00	$2 534.53	$1.96	Also 47 feet 6-inch pipe.
1901	10	5 430	2 478.28	1 292.21	3 583.47	205.40	173.48	7 732.84	1.43	105 ft. 6-inch, 77 feet 12-inch, 40 feet 8-inch
1901	12	1 292	458.40	108.72	1 153.76	52.00	54.22	1 827.10	1.41	
1904	8	3 007	1 035.66	275.67	1 503.50	91.20	72.99	2 979.02	0.99	
1904	6	2 543	1 134.97	412.33	933.28	61.88	37.55	2 584.01	1.02	
1905	6	4 550	1 854.23	491.38	1 966.16	96.00	385.82	4 793.59	1.05	Includes 4 hydrants and changing 25 services
1907	18	6 545	4 248.80	232.00	9 228.45	440.60	523.60	14 673.45	2.24	
1907	14	2 031	552.52	141.00	2 295.03	124.20	86.00	3 201.27	1.56	
1907	16	8 891	4 820.00	1 411.12	11 024.84	420.00	1 179.39	18 855.35	2.12	

RECORD OF LEAKS AT PLYMOUTH, MASS.

Year.	No. Miles Pipe.	No. Leaks.	No. Leaks per Mile.	Total Cost Leaks.	Cost per Mile.	Cost per Leak.
1874		9		$47.30		
1875		53		249.45		
1876		8		42.75		
1877		9		42.87		
1878		14		43.05		
1879		7		23.25		
1880	19.6	57	2.85	253.11	$12.90*	$4.44
1881	20.34	72	3.54	321.06	15.74	4.46
1882	20.54	33	1.6	159.22	7.75	4.83
1883	20.85	22	1.05	159.52	7.65	7.26
1884	21.52	46	2.13	263.46	12.24	5.73
1885	21.75	30	1.32	174.28	8.01	5.81
1886	23.6	38	1.61	231.91	9.82	6.10
1887	27.37	55	2.0	385.64	14.09†	7.02
1888	28.21	89	3.15	592.29	20.96	6.66
1889	28.7	31	1.08	261.90	9.13	8.45
1890	29.05	32	1.1	150.63	5.18	4.71
1891	29.23	35	1.18	201.79	6.90	5.77
1892	32.00	35	1.09	207.83	6.49	5.94
1893	33.09	39	1.11	204.74	6.19	5.24
1894	33.4	41	1.22	241.02	7.22	5.88
1895	34.32	34	.99	179.91	5.24	5.29
1896	34.45	46	1.34	310.13	9.00	6.74
1897	35.00	50	1.43	389.10	11.12	7.79
1898	35.17	42	1.2	232.84	6.62	5.54
1899	36.07	109	2.71	468.42	12.98‡	4.30
1900	37.33	58	1.55	402.35	10.78	6.94
1901	44.43	102	2.29	733.42	16.50§	7.19
1902	45.56	81	1.77	782.07	17.16	9.66
1903	45.8	54	1.20	496.81	10.90	9.20
1904	46.44	59	1.27	438.75	9.44‖	7.44
1905	46.88	41	.87	516.40	11.02‖	12.60
1906	47.33	25	.53	315.40	6.67	12.61
1907	49.43	26	.52	622.45	12.56**	23.92
Average, (1880-1907.)	33.12	49.36	1.49	$349.86	$10.56	$7.09

*1880. Pump started April, 1880.

†1887. High service put on December 20, 1887, causing many extra leaks in pipe thirty-four years old, never before exposed to high pressure.

‡1899. Lightning caused 30 or 40 leaks.

§1901. Twelve leaks occurred in old 2-inch galvanized iron. Since replaced.

‖1904 and 1905. Extremely cold; frost many places 5 feet deep; 360 feet pipe lowered.

**1907. This year one leak was very expensive. Frost was 5 feet deep. Leak did not appear on surface for several days, causing a settling in sidewalk and street, which had to be replaced.

wage paid for a working day of eight hours, for each laborer. The foreman receives $3.00.

The pipe-making gang numbers about sixteen men, but only four are kept on the regular gang and the others are hired as they are needed.

Upon friction loss in their cement-lined pipe, Mr. Blackmer says, —

"I find in our records a report made to the Plymouth Water Commissioners by Mr. Clemens Herschel, dated September 1, 1875. In this report he states that he measured the discharge of our 10-inch main from Little South Pond to our distributing reservoir in town, a distance of about 16 000 feet under a six-foot head, and found it to be about 10 500 gallons per hour.

"If I have made no error in computation, this corresponds to a value of C = 93 in the Chezy formula. [This corresponds to C = 103, approximately, in the Hazen and Williams formula. L. M.]

"I have also a section of 10-inch main (now being replaced by 18-inch) from Little South Pond to our pumping station at Lout Pond, a distance of 7 500 feet. This main discharges freely into Lout Pond under a head of approximately 18 feet, but subject to some variation. Lout Pond is about fifteen acres in extent, with a very small watershed. For two years I have kept daily records of the height of this pond and put it on a sheet with our daily pumping record. From this sheet it is apparent that when our daily average pumping exceeds 750 000 gallons, Lout Pond falls, and when our pumping falls below 700 000 gallons, Lout Pond rises. I have assumed from this (but with what per cent. of error I do not know) that the capacity of this 10-inch main was between 700 000 gallons and 750 000 gallons in twenty-four hours. Assuming that 725 000 gallons is approximately correct, I obtain a value of C = 90 in Chezy formula. [This corresponds to C = 109, approximately, in the Hazen and Williams formula. L. M.]

"I am aware that these data may not be exact, but they are all that appear to be on record, and I hope may be of interest to you."

PORTLAND, ME. (Information developed in the valuation proceedings in the suit of the Portland Water District *v.* Portland Water Company *et als.*, March, 1908.)

In the years 1868–9 the Portland Water Company laid a 20-inch wrought-iron cement-lined supply main, about 15.2 miles

long, from Sebago Lake to the city of Portland. Data as to the cost of this main are unfortunately lacking.

In the years 1875–9, however, a second wrought-iron cement-lined supply main was laid from the lake to the city. The upper portion of this, approximately 3½ miles in length, was 26 inches in diameter; the lower portion, approximately 11.4 miles in length, 24 inches in diameter. The actual cost of this compound main was fortunately developed from the books of the company and is given in substance below, as some of the unit costs to be derived therefrom are interesting and valuable.

(The original pipe distribution, comprising pipes from 4 to 16 inches in diameter, was also laid of wrought-iron cement-lined pipe, but substantially all of this was abandoned within a period of twenty years, and relaid with cast-iron pipe, and figures of its cost are not available.)

It should be stated that the static pressures upon this supply main are approximately as follows:

4	miles,	under	0– 40	pounds	pressure	per	square	inch.
2.7	"	"	40– 60	"	"	"	"	"
4.9	"	"	60– 80	"	"	"	"	"
2.3	"	"	80–100	"	"	"	"	"
0.9	"	"	100–120	"	"	"	"	"

The main is stated to have been built with a factor of safety of approximately 3, but the computation of the factor of safety under several assumed heads indicates that the actual factor of safety is probably not in excess of 1.5 at the points of maximum pressure, assuming always static pressures, and ignoring alike the decrease in pressure due to friction and the increase in pressure due to water hammer or other causes.

STRENGTH OF RIVETING OF WROUGHT-IRON CEMENT-LINED PIPE BETWEEN SEBAGO LAKE AND PORTLAND.

Wrought-iron plate, No. 12 and No. 14 gage; tensile strength	60 000* lbs. per sq. in.
Wrought-iron plate, No. 12 and No. 14 gage; bearing strength	60 000* " " "
Rivets of wrought iron; shearing strength	50 000 " " "
For field riveting, allow, shearing strength	40 000 " " "
Efficiency of best single riveted joint	55%
Efficiency of best double riveted joint	70%

* For ⅜ inch and heavier plate, tensile strength = 50 000 lbs. per sq. in.

March 27, 1908, examined another section of 20-inch cement-lined pipe and found following measurement:

Internal diameter of wrought-iron cement-lined pipe.....	19¾ in. and 19¾ in.	24 in.	26 in.
External diameter of wrought-iron shell.....	22 „ „ 21¾ „	26 „	28 „
Type of joint.....	Slip	Sleeve	Sleeve
Gage of plate (Birmingham)..	14	12	12
Thickness of plate.....	0.083 in.	0.109 in.	0.109 in.
Rivets, diameter.....	¼ „	⅜ „	⅜ „
Rivets, pitch.....	1¼ „	1 „	1 „
Riveting.....	Single	Single	Single

Under Assumed Head of 250 Feet (= 108 Pounds per Square Inch) from Sebago Lake:

Tension on plate, pounds per square inch.....	14 200	12 900 (Note A below)
Factor of safety (60 000).....	2.3	2.6
Shear upon rivets, pounds per square inch.....	29 900	12 700
Factor of safety (40 000).....	1.4	3.1
Bearing upon plate, pounds per square inch.....	70 700	34 400
Factor of safety, (60 000) (Based on 100 000 pounds = 1.4)	Failure	1.7

Under Assumed Head of 200 Feet (= 87 Pounds per Square Inch) from Full Standpipe.

Tension on plate.....	11 400	10 400 (Note A below)
Factor of safety.....	2.8	3.2
Shear.....	24 000	10 100
Factor of safety.....	1.6	4.0
Bearing.....	56 500	27 500
Factor of safety (Based on 100 000 pounds = 1.8).....	Failure	2.2

Under Assumed Head of 150 Feet (= 65 Pounds per Square Inch) from Bramhall Reservoir.

Tension on plate.....	8 500	7 700 (Note A below)
Factor of safety.....	3.9	4.3
Shear.....	18 000	7 600
Factor of safety.....	2.2	5.3
Bearing.....	42 500	20 700
Factor of safety (Based on 100 000 pounds = 2.4).....	1.4	1.5

NOTE: No allowance for water hammer. A factor of safety of 1.0 is equivalent to failure.

NOTE A. The 26-inch is under very small pressure.

In comparison with these factors of safety of 1½ to 3 or more, it should be noted that modern steel pipes are usually built with a factor of safety of 5 (or at least 4) and cast-iron pipes with a factor of safety of 15 more or less.

COST OF BUILDING 24-INCH WROUGHT-IRON CEMENT-LINED SUPPLY PIPE FROM END OF 26-INCH PIPE ON WARD'S HILL TO THE CITY OF PORTLAND.

Length, 60 221 feet.

The work was substantially done in the year 1878–9.

ACTUAL COST. (1878–9.)

Rights of way, land damages, etc.		$1 579.14
Cast-iron pipe, specials, castings, valves, etc.		5 024.08
Wrought-iron sheets for pipe:		
441 502 pounds at 2.43 cents	$10 728.50	
1 449 562 „ „ 2.30 cents	33 339.92	
		44 068.42
Making pipes 9 feet long:		
1 593 pieces at $2.15, and		
5 073 „ „ 2.00		13 570.95
Making joint rings, inside rings, and special rings:		
7 061 rings, weighing 646 310 pounds, at 1.95 cents, approximately, per pound		12 615.14
Total labor, 24 775 days at $1.28 approximate average; day labor being paid from $1.00 to $1.25; foremen, $3.50		31 807.11
Cement, 20 621 barrels Rosendale		20 180.50
Freight, cartage, etc.		4 148.91
Engineering, incidentals and miscellaneous expenses, amounting to 8.32 per cent. approximately		10 919.67
		$143 913.92
Deduct land damages		1 579.14
Net amount		$142 334.78
Cost per foot		$2.36
Equivalent cost per foot for year 1908 (estimated)		$3.02

COST OF BUILDING 26-INCH WROUGHT-IRON CEMENT-LINED PIPE FROM SEBAGO LAKE TO THE JUNCTION ON WARD'S HILL WITH 24-INCH PIPE LEADING TO THE CITY OF PORTLAND.

Length, 18 450 feet. Date of construction, 1875–6.

	Per Lb. Cents.	Actual Cost in 1875–6.	Equivalent Prices as of 1908.
Wrought iron sheets, No. 12 Birmingham gage, 635 679 pounds at	3.32	$21 230	$18 670
Trimming, rolling, riveting, and finishing 2 066 pipe 9 feet long at $2.50, equivalent to	0.78	5 020	4 430
Rings	0.90	5 590	4 920
Equiv. rate per lb., 1875–6	5.0		
„ „ „ „ 1908	4.4		
Cement (Rosendale), 74 071 barrels at $1.36 and $1.53½ per bbl		10 170	7 500
Contract for laying		28 310	42 465
Valves		237	237
Specials		85	85
Lumber		608	1 074
Contract work		141	150
Total		$71 391	$79 531

Cost per foot (including 11.4 per cent. for engineering and contingencies)	$3.87	$4.31

The cost of this 26-inch pipe line was excessive, owing to deep cut work, a considerable amount of which was in quicksand.

Mr. Allen Hazen, member of this Association, who was one of the engineers retained by the Water District in the valuation of the Portland water works, made the following interesting analysis of these items of cost:

ESTIMATE OF COST OF REPRODUCING CEMENT-LINED PIPE AT PORTLAND.

	26-INCH.		24-INCH.		20-INCH.
	Actual Price and Quantity.	Estimates for Present Conditions.	Actual Price and Quantity.	Estimates for Present Conditions.	Estimates for Present Conditions.
Cost of sheets, per pound	$0.0342	$0.0275	$0.0233	$0.0275	$0.0275
Cost of cement, per barrel	1.40	1.00	0.98	1.00	1.00
Cost of joint castings, pound,	0.0280	0.0275	0.0195	0.0275	0.0275
Cost of making pipe, per pound	0.00756	0.0125	0.00718	0.0125	0.0125
Weight per foot, pounds	37.0	.....	31.4	.....	21.0
Barrels cement per foot	0.405	.....	0.342	.....	0.310
Weight joint rings, pounds	71.0	.....	91.0	.....	70.0
" " " per foot	8.3	.....	10.7	.....	8.2
Cost per linear foot of:					
Sheets	$1.26	$1.02	$0.73	$0.86	$0.58
Making pipe	0.28	0.46	0.23	0.39	0.26
Joint castings	0.23	0.23	0.21	0.29	0·23
Cement	0.57	0.40	0.33	0.34	0.31
Gates, valves, etc.	0.05	0.04	0.08	0.07	0.06
Labor and laying	1.48*	2.22	0.53	0.80	1.25
Sum	$3.87	$4.37	$2.11	$2.75	$2.69
Total actual cost, including all special obstacles, engineering and contingencies	$3.86	.....	$2.39	.....	.....
Ratio of total cost to sum of items above given	1.00	.....	1.13	.....	$1.06
Total estimated cost, including engineering and contingencies	.....	$4.37	.....	$3.10	2.85
Fair value to use is estimate on which 14 per cent. for engineering and contingencies is to be added	.....	3.85	.....	2.72	2.50

* The contract price at ordinary depths of cut, and exclusive of rock, was 70 cents per linear foot. The difference, 78 cents per foot, represents the additional allowances for extra depth and for rock and for tunnel, and for all contingencies because of the character of the ground. These additional costs would naturally be somewhat higher on the 26-inch line than on the 24-inch line, and the route of the 20-inch line covers substantially the same space as that occupied by both the 26-inch and 24-inch lines.

Pitometer gagings were made of the mains from Sebago Lake to the city of Portland covering a period of a little over one month, March, 1908. From these the following coefficients of discharge applicable to the Hazen-Williams hydraulic formula were determined:

26-inch, $c=100$,
24-inch, $c=100$,
20-inch, $c=90$,

but there was reason to believe that there was an unknown cross connection from the 26-inch and 24-inch compound high-service line to the 20-inch low-service pipe line. This makes it *probable that the actual coefficient (for Hazen-Williams' formula) was about* c = 95 *for all three of these pipe lines.*

This coefficient is as low as would be expected from cast-iron pipe of like age and was a surprise to the engineers, who had looked for a coefficient of from 110 to 120. The low value is probably to be accounted for, in part at least, by the internal restrictions at the pipe joints, which were plastered inside after laying, and to a slightly smaller *actual* than nominal diameter (the coefficient being figured upon the nominal pipe diameter).

Revere and Saugus, Mass. (Information from Supt. A. S. Burnham.)

The town of Revere had a population of 12 659 in 1905. The town of Saugus had a population of 6 253 in 1905. The water-works system was installed in 1884, the main pipe being cement lined. In 1894 further employment of this kind of pipe was abandoned, the reason given by the superintendent being that the price of cast-iron pipe sunk to a point where competition with cement-lined pipe was possible.

The original works were controlled by a water company and were taken over by the town in 1905. No records previous to this time were obtainable from the present management. At the present time there are about 18 miles of cement-lined pipe ranging in size from 4 inches to 16 inches, and 19 miles of cast-iron pipe.

The superintendent states that he remembers a case about fourteen years ago, the exact date being forgotten, when lightning struck a house and followed the service pipe into the main and disrupted the joints of five or six lengths of pipe.

A rough summary of the repair account for two years, taken from the books of the Water Department, is given in the following table:

	No. of Leaks.	Cost of Repairs.	Miles of Pipe.	Cost of Repairs per Mile of Pipe.
TEN MONTHS OF 1905.				
Cement-Lined Pipe.....	19	$245.00	18	$13.60
Cast-Iron Pipe.....	6	37.00	18	2.05
FOR THE YEAR 1906.				
Cement-Lined Pipe.....	9	$63.00	18	$3.50
Cast-Iron Pipe.....	4	14.00	19	0.74

Average pressure, 70 pounds. Average age of pipe, 19 years.

RIVERTON, N. J. (Information received from Mr. Howard Parry, superintendent of the Riverton and Palmyra Water Company.)

"We have used the Phipps patent cement pipe, as manufactured by the American Pipe Manufacturing Company of Philadelphia, Penn., nearly exclusively.

"We have about twenty-two miles of pipe in our system — it is all cement (except about two miles of 4-inch cast-iron) that was put in on the outskirts of our town, and paid for largely by the consumers we were supplying, iron being down in price to less than one cent a pound at that time. Our company was incorporated in 1888, and the works were built in 1889. The cement pipes, 4-inch, 6-inch and 8-inch, put down in 1889, are just as good now as when first laid; the 16-inch, put in recently, seem also to be O.K. We have had occasion to put in two fire hydrants within the last ten days, which necessitated cutting the pipe to put in the specials. We found this cement pipe in perfect condition, perfectly smooth inside. No filling up. Same diameter as when laid. The cement gets harder and better with age — as our engineer reports when drilling for new taps. We have no leaks to speak of. I do not believe they will average one a year on our whole system, after the water has been turned on and in service. On some of our new extensions there have been a few leaks from imperfect joints, which developed when the water was turned on, but after they were repaired, we have had no further trouble with them. I think a good deal of this trouble was caused by an intemperate joint maker. We were told by the 'cast-iron men' the life of our cement pipe would be about fifteen years; they have been in now eighteen years, and are

just as good, if not better, than when laid, at the same price per foot. We would not lay another foot of cast-iron pipe. I think the Phipps cement pipes are like wine, they get better with age,— the older the better. I do not know how they will answer under high pressure. Our pressure is low, — from 20 to 50 pounds, standpipe pressure, at different parts of our system, — but I should think they could be made to stand any pressure needed.

" All complaints from rusty water are from those consumers using water from the iron pipes. The cement pipe delivers the water to the consumer just as clear and pure as when it is pumped. We have as good a pipe as can be laid, and know of none better."

SPRINGFIELD, MASS. (Information from Elbert E. Lockridge, chief engineer.)

Letter addressed to Mr. E. V. French, February 10, 1908.

" Your letter of February 5, 1908, is at hand. In regard to the cement-lined pipe in Ludlow and this city, I am sending you a copy of the report of the Board of Water Commissioners for 1876. This is a report on the work done in 1875. I call your attention particularly to page 23, in which a discussion on the value of cement-lined pipe is entered into. The arguments as they appear at that time are well set forth between pages 23 and 29. This is included in Mr. Phineas Ball's report.

" On page 29 you will see some records of some of Worcester's experience, and also a statement of the way cement-lined pipe should be laid. On page 45 you will find a table which shows the size and amount of pipe laid each year. You will see in this table that the 24-inch main line was laid in 1874, with but a few lengths in 1875. The general impression had been, and, in fact, it was the impression which I had, that most of this was laid in 1875. However, this probably is conclusive.

" On pages 46 and 47 is a list of the cement pipe laid in 1875, by streets.

" It is but fair to state that this year we are planning to replace a portion of these pipes laid in that year. Some of them have given very satisfactory service throughout the entire time. Others have not and have been the cause of breaks which tore up the pavement, as was the case of the Locust Street break two or three weeks ago, which did considerable damage to the street car company as well.

In regard to the 24-inch main line from Ludlow to this city, I have been told by those who remember its laying that a considerable portion of it at the reservoir end had to be taken up and

relaid with cast iron the first year. I have been told that the reasons for this were partly from settling, causing breaking, and I have also wondered if it was not practically due to the mixture of the cement, as you will note in this statement: 'During the past year they had used only neat cement, while formerly some sand had been mixed with the cement.' Since this replacing, the first year after the pipe was laid, I believe there have been no repairs, or if any, very slight repairs on the main pipe. We have believed that the trouble with cement-lined pipe was largely due to breaking and chipping of the cement from the inside surface when the tap was made, thus exposing the wrought iron to the elements.

"I am also sending you a copy of the 1878 report, which is chiefly valuable as indicating the kind of pipe being laid. You will notice on the list on page 21 but one cement pipe listed, and I have been told that following this date no cement-lined pipe has been laid in the city. You will note from the last report the mileage still remaining."

See also Phineas Ball's report quoted on pages 3–9.

WALTHAM, MASS. (Information from Supt. Leroy Brown and Ex-Supt. George E. Winslow.)

Waltham had a population in 1905 of 26 282. Water works were constructed in 1872, the mains being cement-lined pipe. In 1887 the further use of this pipe was practically abandoned, and since that time substitutions have been made until at the present time there is left only about one mile of cement pipe. In 1887 there were about twenty miles of cement-lined pipe, ranging in size from 4 inches to 16 inches.

The reason given by Mr. Brown for giving up the use of this pipe was leaks in the joints, also trouble in making connections and care necessary in opening and shutting gates to prevent water hammer, which is liable to cause breaks.

On July 4, 1879, lightning caused the destruction of 300 feet of 6-inch pipe, cast iron being substituted at a cost of $263. July 12, 1883, lightning again caused a small leak and it was repaired at a cost of $20. August 3, 1889, 32 feet of 4-inch pipe was destroyed, and on August 12, 1891, 1 070 feet of 6-inch pipe was destroyed by lightning.

The Waltham report for 1895 contains reference to electrolysis in connection with the cement-lined pipe, and states that several

pieces dug up near the electric-car tracks were badly pitted and that the pipe was rendered practically worthless.

Year.	No. of Leaks in Cement-Lined Pipe.	Total No. of Leaks.	Cost of Repairs on Cement-Lined Pipe.	Cost per Leak.	Cost per Mile.
1883	13	19	$232.00	$17.84	$11.60
1884	15	27	245.00	16.33	12.25
1885	6	13	45.00	7.50	2.25
1886	7	12	400.00	57.15	20.00
1887	5	12	154.00	30.80	7.70
1888	8	10	179.00	22.38	8.95
1891	37	41	1092.00	29.52	54.60
Average ..	13	19.1	$353.30	$25.79	$16.76

During this period there were about twenty miles of cement-lined pipe in the system.

The large number of leaks noted in 1891 was partly due to the beginning of construction of a sewerage system in the city. Laborers in digging trenches for sewers caused damage to the water pipes. It should be noted that the cost of repairs given in the above table generally includes the substitution of cast-iron for the old cement-lined pipe.

WATERTOWN, MASS. (Information from former Supt. John H. Perkins.)

Watertown had in 1905 a population of 11 202. Water works were constructed in 1884, about fourteen miles of cement-lined main pipe, from four to fourteen inches in diameter, being laid. Since about 1890 no cement-lined pipe has been laid. All pipe construction since that time has been of cast iron. Mr. Perkins claimed that the reason for making the change was that cement-lined pipe could not be bought after 1890 in the market, and as they had no conveniences for making pipe themselves, cast iron was substituted. Since the supply was introduced about one-half mile of cement-lined pipe has been removed and replaced by cast-iron. Some of the cement-lined pipe, however, is still in excellent condition. A piece of 6-inch pipe on exhibition in the office of the

water works, which was stated to have been in the ground for eighteen years before removal, is in first-class condition.

The number of leaks in the whole system reported during 1906 was five, and it is stated that the cost of repairs is only $3.05 per mile. This, of course, was on the total length of main in use, 37 miles, of which about fourteen are of cement-lined pipe. At the office of the water works it is stated that great care is exercised in opening and shutting gates to prevent water hammer, as this has caused leaks at various times. It is also stated that pipes have been particularly liable to deterioration where they are near the electric railroad tracks, presumably due to electrolysis.

WILDWOOD, N. J. (Information received from Mr. Clarence Miller, superintendent of the Wildwood Water Works Company.)

"I have had some experience along this line, having had charge of the present plant for about five years and was also connected with the same company at Phœnixville, Penn., for some time. The pipe we use is manufactured by the American Pipe Manufacturing Company, of Philadelphia, and is known as cement-lined pipe, — same being constructed as follows: Outside covering of jacket iron about 1-32 inch in thickness, then there is a layer of cement about 1 inch in thickness; inside of this there is another covering of iron about 1-16 inch in thickness, and then this is lined on the inside with about $\frac{3}{4}$ of an inch of cement. The inside lining of cement is of Hoffman Rosendale, the outer layer of cement being of the best grade of Portland. This makes a very nice pipe in appearance and it is capable of carrying anything up to about 125 pounds pressure to the square inch. The connections or joints on this pipe are comprised of a male and female ring which fit neatly together, this being covered with cement, then a slip sleeve is used, which holds the cement in place, and then an outside covering of cement is used to keep the sleeve from corroding or rusting from the dampness. It is necessary, when laying this kind of pipe, to let the joints set about four weeks before turning on the pressure, so as to insure their being dry and hard. In tapping this kind of water main, we use a steel girth with a cast-iron saddle (same being drilled and tapped to suit the specified size of connection); under this saddle we use a small piece of rainbow packing about $\frac{1}{8}$ inch in thickness, which acts as a gasket and makes a water-tight joint. The corporation is connected to the saddle and then a tapping machine especially constructed for this make of pipe is used in drilling

the pipe. For cleanliness, I have never found anything in the pipe construction to equal it, as it is the same as a stone jar on the inside and there is never any corrosion of or deposit upon the pipe. I have removed some 4-inch pipe that has been in service for over eleven years, and it was just as clean as the day it was laid (same was removed to be replaced with a larger size) and did not show any defects from long using."

WOBURN, MASS. (Information from the registrar.)

Woburn had a population in 1905 of 14 402. A water-works system was installed in 1873. The use of cement-lined pipe was given up in 1899, but no work has as yet been done toward the replacement of cement lined with cast iron, new construction only being of cast iron. In 1874 there were 24 miles of cement-lined pipe, and at the present time there are about fifty-one miles together of cement-lined pipe with some five miles of cast-iron

WOBURN, MASS.

Year.	No. of Leaks.	Miles of Pipe.	Leaks per Mile of Pipe.	Cost of Repairs.	Cost per Leak.	Cost of Repairs per Mile.
1879–1886	51(av.)	38(av.)	1.34	.....	.....	.....
1890	23	45	0.51	.....	.....	.....
1891	9	47	0.19	$120.00	$13.30	$2.50
1892	30	49	0.61	334.00	11.10	6.80
1893	24	49	0.49	373.00	15.50	7.60
1894	25	50	0.50	263.00	10.50	5.30
1895	68	51	1.33	601.00	8.80	11.80
1896	57	51	1.12	646.00	11.30	12.70
1897	92	51	1.80	1 199.00	13.00	23.50
1898	32	51	0.63	414.00	12.90	8.10
1899	34	52	0.65	422.00	12.40	8.10
1900	50	54	0.93	752.00	15.00	13.90
1901	43	54	0.80	741.00	17 20	13.70
1902	35	54	0.65	832.00	23.80	15.40
1903	34	55	0.62	801.00	23.60	14.60
1904	59	55	1.07	2 318.00	39.30	42.20
1905	53	55	0.96	1 164.00	22.00	21.20
1906	45	57	0.79	1 084.00	24.10	19.00
Average, 1897–1906	47.7	53.8	0.89	$972.70	$20.40	$18.08

pipe. The average age of the pipe is about twenty-three years. The average pressure in the city is 70 pounds.

Almost every annual report contains references to breaks caused by lightning. In 1886 about a mile of pipe was so damaged by this cause that reconstruction was recommended. From 1884 to the present time some two hundred leaks have been attributed to lightning. Leaks are attributed principally to lightning, rust, bad joints, water hammer and thin lining.

The number of leaks and the cost of annual repairs are shown in the table on page 55.

OTHER WROUGHT-IRON CEMENT-LINED PIPE SYSTEMS.

Mr. J. W. Ledoux, chief engineer of the American Pipe Manufacturing Company, of Philadelphia, who has had much experience in the installation of wrought-iron cement-lined pipe systems, has kindly furnished the writer with the following list of works for which a considerable proportion if not the entire pipe system has been built of cement-lined pipe, and it was the intention of the writer to communicate with these water works in regard to their experience with this pipe, but lack of time and space have alike prevented his doing so, though he is still in hopes that Mr. Ledoux himself will contribute to the discussion of this paper.

Springfield Water Company	Lansdown, Penn.
North Springfield Water Company	Bryn Mawr, Penn.
East Jersey Coast Water Company	West Asbury Park, N. J.
Wildwood Water Company	Wildwood, N. J.
Moorestown Water Works	Moorestown, N. J.
Riverton Water Company	Riverton, N. J.
Norfolk County Water Company	Norfolk, Va.
Sumter Water Company	Sumter, S. C.
Paris Mountain Water Company	Greenville, S. C.
Tallahassee Water Company	Tallahassee, Fla.
Milledgeville Water Company	Milledgeville, Ga.
Opelika Water Company	Opelika, Ala.
LaGrange Water Company	LaGrange, Ga.
Derry Water Company	Derry, Penn.
Skaneateles Water Company	Skaneateles, N. Y.
Jordan Water Works	Jordan, N. Y.

Compiled from inter

City or Town.	Population in 1905.	Works Built.	Length of C. L. Pipe in Miles. 1886.	1906.	Total Miles Extension. 1886–1906.	Exten of C Aband
Attleboro, Mass.	12 702	1873	16	None	About 36	188
Arlington, Mass.	9 668	1872	About 12	4	.....	187
Brockton, Mass.	47 494	1880	3	3	69	...
Beverly, Mass.	15 223	1869	48	32	Over 19	180
Burlington, Vt.	18 640*	1867	19	4	11	...
Chelsea, Mass.	37 289	1867	23	None	....	187
Concord, Mass.	5 421	1874	21	21	12	188
Concord, N. H.	19 632*	1872	Over 30	18	34	188
Fitchburg, Mass.	33 021	1873	17	None	40	187
Gloucester, Mass.	26 010	1884	.....	19	....	189
Hartford, Conn.	79 850*	1857	15	3	....	188
Lee	3 972	1883	10	10	....	188
Lynn, Mass.	....	1871	63	32	30	188
Malden, Mass.	38 037	1870	About 45	20	35	189
Manchester, N. H.	56 987*	1872	27	4	62	187
New London, Conn.	17 548*	1871	22	About 8	39	188
Pittsfield, Mass.	25 001	1855	3	None	....	...
Plymouth, Mass†	11 119	1885	23	47	24	‡
Revere and Saugus	12 659 / 6 253	1884	About 18	18	....	189
Springfield, Mass.	73 540	1864	48	33	80	188
Waltham, Mass.	26 282	1872	20	1	21	188
Watertown, Mass.	11 202	1884	14	13	....	189
Whitman, Mass.	6 521	1883	12	12	12	188
Woburn, Mass.	14 402	1873	39	51	18	188
Worcester, Mass.	128 135	1845	41	None	97	188

STATISTICS RELATIVE TO THE USE OF CEMENT-LINED MAIN PIPE.

Compiled from interviews and from reports. Some figures necessarily approximat

	Total Miles Extension. 1886–1906.	Extensions of C. L. Abandoned.	Replacement Begun.	Reason Given for Abandonment.
	About 36	1880	1898	Trouble making connections
	.....	1872	About 1895	.....
	69	....	....	.....
	Over 19	1894	About 1895	Poor condition of old pipe
	11	....	....	.....
	....	1875	1875	Leaks caused by making connections
	12	1888	Not begun	.....
	34	1887	1898	Breaks from rust
	40	1877	1883	.....
	....	1896	1896	Poor condition
	....	1884	1886	Frequent breaks; expense of repairs
	....	1883	Not begun	.....
	30	1884	1890	.....
	35	1890	1892	.....
	62	1877	1877	Trouble in making repairs
8	39	1889	1889	.....
	....	....	....	Freezing. Poor workmanship
	24	‡	....	.....
	....	1894	Not begun	Lessened cost of cast iron
	80	1882	1886	.....
	21	1887	1887	Leaks in joints; trouble in making connec
	....	1890	Not begun	Cement pipe could not be obtained; tro from electrolysis
	12	1883	Not begun	No appliances for making C. L.; C. I. convenient
	18	1899	Not begun	Lightning, rust, bad joints, thin lining
	97	1880	About 1880	.....

* 1900. † Since 1900, Phipps patent. ‡ Stil

IPE.

ximate only.

ent.	Approx. Age of Pipe when Replacement Began.	Pressure Lbs. per Square Inch.	Average Annual Cost of Making Repairs per Mile of C. I. Pipe.	Trouble from Lightning.
	25 yrs.	65–100	.....	1 accident
.....	23 yrs.	50–90	.....	2 accidents; 1 cost $974.
.....	...	50	.....	.....
	26 yrs.	72	$49.00 (1899–1906)	3 000 ft. required replacem't
.....	?	70–85	.....	.....
as	8 yrs.	50–75	.....	1 accident
.....	.....	....	$5.00	Some trouble
	26 yrs.	45–75	$18.00 (1900–06)	400 ft. replaced
.....	10 yrs.	75–165	.....	.....
	12 yrs.	15–75	.....	Considerable trouble
s	29 yrs.	.....	.....	.....
.....	.....	.....	$20.00 about	1892 damaged 2 000 ft.
.....	19 yrs.	.....	.....	.....
.....	22 yrs.	65	$30.00 about	Considerable
	5 yrs.	60	.....	1 accident
.....	18 yrs.	60–75	.....	1 stroke caused damage $940
	?	60	.....	Some trouble
.....	.....	50	$11.00 (1902–6)	.....
	.....	70	.....	1 accident
.....	22 yrs.	30–120	$10.00 (1900–6)	.....
onnections	15 yrs.	50–70	$17.00 (1883–91)	1 400 ft. replaced; 4 accidents
l; trouble				
	13 yrs.	.....	.....	.....
C. I. more				
	.....	65	Very small	None
ng	.....	70–75	$14.00 (1891–6)	200 leaks; 5 000 ft. replaced
.....	35 yrs.	70–150	$52.00 (1884–86)	.....

‡Still in use.

RESULTS OF INQUIRY UPON EXPERIENCE WITH WROUGHT-IRON CEMENT-LINED PIPE IN NEW ENGLAND.

In order to bring into convenient and comparable form the results of experience in New England with pipe of this character a parallel column is subjoined giving the views expressed in 1888 by water-works superintendents in different communities as typified by the data contained in the *Engineering News* article above referred to, and the views developed by the writer twenty years later, that is, in the year 1908, first, as applied to pipe distribution systems, and second, as to supply mains; and in a third table are condensed the results of the writer's inquiry in 1908.

Experience with and Opinions upon Wrought-Iron Cement-Lined Pipe in Various Cities up to the Year 1888 and in the Year 1908.

1888.	1908.
Boston, Mass.	
Gave it up on account of rusting and bursting.	Using cast-iron pipe only.
Brockton, Mass.	
Reports cement-lined pipe all right and no leaks.	No distribution pipe. Only three miles supply pipe.
Brooklyn, N. Y.	
Used it from 1859 to 1884 and gave it up as unserviceable.	Using cast-iron pipe only.
Cambridge, Mass.	
None laid for fifteen years.	Using cast-iron and steel pipe.
Chelsea, Mass.	
Used some such pipe for twenty-one years and its condition is fairly good, but cast-iron pipe was found to be more reliable and economical.	None remains. Using cast-iron only.
Concord, N. H.	
Has used cement pipe for sixteen years. It is in good condition.	Began replacement in 1898. Fourteen out of twenty-eight miles in 1887 now in use.
Fitchburg, Mass.	
Used it from fourteen to seventeen years, but gave it up because repairs cost more than the change to cast-iron pipe.	Using cast-iron pipe.

1888.	*Hartford, Conn.*	*1908.*
Has twelve miles of cement-lined pipe and has used it for twenty-five years, but it has given much trouble from breaks.		Using cast-iron pipe.
	Malden, Mass.	
Laid some twenty years ago and is replacing it with cast-iron.		Using cast-iron pipe.
	Manchester, N. H.	
Used it for fifteen years, but is not laying any more on account of leaks and breaks.		Cast-iron pipe.
	Meriden, Conn.	
Has used it since 1869. Condition poor.		Cast-iron pipe.
	New Bedford, Mass.	
Considers it unreliable.		Cast-iron pipe.
	New Haven, Conn.	
Considers it reliable and contemplates no change.		Cast-iron pipe.
	New London, Conn.	
Would on no account lay a large main of cement-lined pipe, and small mains only with the best of materials and workmanship.		Eight miles (out of twenty-two in 1886) remain.
	Pittsfield, Mass.	
Used it since 1855. Condition good so far as known.		None remains.
	Plymouth, Mass.	
Using cement-lined pipe exclusively.		Still using cement-lined pipe exclusively. Giving good satisfaction.
	Portland, Me.	
After twenty years' experience has taken all the cement-lined distribution pipe up because it could not stand the pressure. Supply mains in good condition.		Cast-iron pipe only for distribution system. Supply mains still in use, but new cast-iron pipe or steel mains will probably soon be laid.
	Providence, R. I.	
Considers the pipe treacherous.		Cast-iron pipe.
	Salem, Mass.	
In use for twenty years and considered good.		Appropriations recently made to replace cement-lined pipe with cast iron.

1888.	*Somerville, Mass.*	*1908.*
Eighty breaks a year.		Using cast-iron pipe.

Waltham, Mass.

Reports that as pipe is beginning to rust no more of it will be laid.	Only one mile of it remains.

Woburn, Mass.

Reports it perfect for pressure of sixty to ninety-five pounds. Does not contemplate change.	In 1899 abandoned further extension work of cement-lined pipe in favor of cast-iron pipe.

Worcester, Mass.

Had a little in use for twelve to sixteen years, but the condition is poor, owing to frequent leaks.	None remains.

REPORTS UPON CEMENT-LINED SUPPLY MAINS.

Brockton, Mass., has a 20-inch and 24-inch pipe, about 3 miles long, one half of it running through a country district, the remainder through one of the outlying streets of the city. The latter half of the main has numerous connections. The original pipe shell was dipped in hot asphaltum and rolled in cement and sand before being placed. The lower end of the main is under about 50 pounds pressure.

1908. Superintendent states that there has been no trouble to speak of with this main during the twenty-eight years of its existence.

Concord, Mass. 1908. Has two 10-inch pipes, approximately $2\frac{1}{2}$ miles each in length, laid from Sandy Pond to the town, the first in the year 1874 and the second in the year 1883. Both pipes are still in active service and have given comparatively little trouble from leakage. The maximum static pressure is approximately 40 pounds.

Concord, N. H., in 1872 laid a 14-inch cement-lined main from Penacook Pond to the city. This main was about 2 miles long, laid largely through a country district, and was under a pressure of about 60 pounds per square inch.

1908. The work of relaying this pipe with cast iron was commenced in 1897 and completed in 1901.

In 1883 a low-service main 18 inches in diameter, about 2 miles long, was laid, and in 1887 a high-service main 14 inches in diame-

ter, about 2½ miles long, was laid, the latter being known as the Penacook extension.

1908. These two last-mentioned mains are said to have given no trouble up to the present time.

Manchester, N. H., has a main about 4 miles long, laid in 1872; part of this is between the pumps and the reservoir, the lower part being subjected to about 60 pounds pressure. This wrought-iron cement-lined pipe has cast-iron bells and lead joints.

1908. This pipe is still in use.

Plymouth, Mass., laid in 1855 a 10-inch main, about 3 miles long, the lower part under a pressure of approximately 50 pounds.

1908. This pipe is still in use and in good condition. A new 18-inch wrought-iron cement-lined supply main is being laid this year from the source of supply to the pumping station and thence to the town.

Portland, Me. A 20-inch wrought-iron cement-lined supply main about 15.2 miles long was laid from Sebago Lake to the city of Portland in the years 1868 to 1869. In the years 1875–9 a second wrought-iron cement-lined pipe supply main was laid from the lake to the city. The upper portion of this, approximately 3½ miles in length, was 26 inches in diameter; the lower portion, approximately 11.4 miles in length, was 24 inches in diameter. (In 1901 the construction of the third line from the lake of 30-inch *cast-iron pipe* was begun and has not yet been completed).

1908. These two wrought-iron cement-lined mains are still in active service, though the construction of a new steel pipe capable of supplying the entire demands of the city will probably be begun next year, in which case the wrought-iron cement-lined pipes will be held as reserves only. Although there has been more or less trouble from leakage, these mains have done good service.

Springfield, Mass., laid in 1874 a 24-inch main about 10½ miles long from Ludlow reservoir to the city.

1908. The engineer of the department states that he understands that a considerable portion of it was relaid during the first year after construction, but that since that time little or no repairs have been necessary.

As summed up in a word, wrought-iron cement-lined pipe has,

generally speaking, proved disadvantageous for water-works uses *in distribution pipe systems*, except in comparatively small communities where street excavations and underground disturbances are of comparatively rare or unusual occurrence and where the pressure upon the pipes has been of moderate amount.

In *conduit* or *supply pipe* service, wrought-iron cement-lined pipe has given much greater satisfaction and has made on the whole a good record for itself, except where the pressure has been great or the pipe has been liable to disturbance by reason of insecure foundation, neighboring excavations, etc.

ADVANTAGES AND DISADVANTAGES OF WROUGHT-IRON CEMENT-LINED PIPE, AS COMPARED WITH CAST-IRON PIPE.

The advantages and disadvantages of wrought-iron cement-lined pipe as compared with cast-iron pipe may be briefly summarized as follows:

Advantages.

1. Freedom from tuberculation, resulting in comparatively small loss in carrying capacity during the life of the pipe.
2. Reasonably high carrying capacity,— technically referred to as high coefficient of discharge,— though less than that of *new* cast-iron pipe.
3. Longevity and durability under favorable circumstances.
4. Lower first cost when compared with cast-iron pipe costing over twenty-seven dollars, or thereabouts, per ton.

Disadvantages.

1. Absolute and relatively greater dependence upon good materials and good work in the manufacture and laying of the pipe.
2. Greater danger of bad or slipshod work in use of cement-lined rather than of cast-iron pipe, particularly in wet trenches or in localities affording insecure foundations.
3. Greater cost than cast-iron pipe under average conditions. (The approximately comparable cost of cast-iron pipe being $27 per ton or thereabouts, and the average price of cast-iron pipe about $25.)

4. Unreliability and danger from bad foundations and nearby excavations made at any time after the completion of the pipe line.

5. Small factor of safety and consequent danger from water hammer, careless manipulation of gates, etc. (The usual factor of safety in wrought-iron cement-lined pipes has been from 3 to 4, in steel pipes from 4 to 5, and in cast-iron pipes from 12 to 15.)

6. Resulting lower limits of safe pressures. Desirable limit, in the opinion of the writer, 65 pounds per square inch; in the opinion of the chief engineer of the American Pipe Manufacturing Company, 100 pounds per square inch.

7. The carrying capacity or coefficient of discharge may not differ materially from that of old cast-iron pipe if the cement pipe is badly made or laid.

8. Danger from lightning and liability of more extended damage therefrom.

9. Difficulty in making watertight joints and connections.

10. Repairs not so easily, cheaply, quickly, or effectively made as for cast-iron pipe.

11. Difficulty in making service pipe connections and greater likelihood of leakage.

CARRYING CAPACITY.

There can be no doubt that the cement coating in the interior of a wrought-iron cement-lined pipe is more satisfactory than the coating of the cast iron, so far as its effect upon the quality of the water is concerned, though the difference may be, and perhaps generally is, practically insignificant. No coating has thus far been found for cast-iron pipe which does not under average conditions sooner or later permit tuberculation. The rapidity and amount of this tuberculation varies with the quality of the pipe coating. Any excrescence of this sort must unquestionably decrease the discharging capacity of the pipe line. This fact is recognized in the design of our cast-iron pipe systems by the adoption of a pipe size or diameter which shall cover this progressive loss in carrying capacity. In other words, the pipe is designed for future rather than for present conditions.

The chief claim of the wrought-iron cement-lined pipe advocates has always been the freedom from tuberculation and maintenance

of carrying capacity of pipe of this character, and it is probably true that the carrying capacity of wrought-iron cement-lined pipe decreases but slightly during the life of the pipe under ordinary conditions.

Comparatively little information has been published of the actual carrying capacities of wrought-iron cement-lined pipes. Without attempting a technical discussion upon this matter, it may suffice to refer to a few examples of recent gagings of pipe of this character. Hazen and Williams in their hydraulic tables quote a range of coefficients for use in the Hazen and Williams formula of the following amount:

Experimenter.	Diameter in Inches.	No. of Observations.	Range of Velocity in Feet. per Second.	Range of c. in H.-W. Formula.	Mean Value of c.
Fanning.....	20	11	1.49–4.04	127–118	122*
Bazin.....	31.50	10	2.78–6.60	148–144	146†

Remarks: *Cement-lined iron. †Experimental conduit.

But the writer is inclined to regard these values as distinctly too high under conditions in this country, so far as he has observed them, though he recognizes and regrets the existing lack of specific data upon this subject.

Pitometer gagings covering a period of four weeks upon the 20-inch and the compound 26–24-inch wrought-iron cement-lined water mains of the Portland Water Company conduit during the recent valuation proceedings indicate a coefficient of discharge in the Hazen and Williams formula (as has already been referred to on page 49) of $c = 95$, though it is probably true that had the pipe been true to nominal diameter the coefficient would have approximated $c = 98$.

Some recent and crude observations at Greensburg seem to indicate a value of approximately $c = 100$, but more accurate experiments with Venturi meters are soon to be made.

The coefficient of the Springfield, Mass., cement-lined pipe is believed to approximate $c = 110$.

Approximate gagings at Plymouth, Mass., indicate a value of $c = 103$ to $c = 109$.

As compared with these coefficients of discharge for wrought-iron cement-lined pipe for use in the Hazen and Williams formula,

the relative discharging capacity of cast-iron pipe may be said to be approximately as follows:

For *new* cast-iron pipe	c=130–140.
For cast-iron pipe 25 years more or less *old*.....	c=100.

While it is true that the coefficient for old cast-iron pipe, thirty-five years or more in age, may be as low as $c = 90$ or even 80, it should be borne in mind that growth in population and hence in water consumption and other causes usually results in the construction of additional supply mains, considerably within the limits of this period, and in such cases the new main is often built sufficiently large to care for the entire consumption of the community without the assistance of the old main. For this reason, and inasmuch as the experience with the modern pipe coating has been comparatively short, it seems reasonable to make a comparison of carrying capacities upon the following basis:

For wrought-iron cement-lined pipe.....	c=120,
For *new* cast-iron pipe.....	c=130,
For *old* cast-iron pipe.....	c=100,

referring by c to the coefficient of discharge to be used in the Hazen and Williams formula. (This formula has been used by the writer as one of the reliable hydraulic formulas now in common use, and as the *most convenient* one on account of its ready application through the Hazen and Williams slide rule.) But attention is called to the fact that in a number of wrought-iron cement-lined pipe lines the actual coefficient c, as based upon the nominal diameter of pipe, varies from $c = 95$ to $c = 110$, and the assumption of a value of $c = 110$ or even $c = 100$ is, therefore, believed to afford a much sounder basis of design than the assumption of the above coefficient of $c = 120$. The difference in the actual process of making pipe must result in far greater variation in internal diameters in cement-lined than in cast-iron pipes, and this is, therefore, an essential factor in design. In order to do full justice to the cement-lined pipe, however, the coefficient $c = 120$ has been assumed for it in the following discussion. If the true coefficient of discharge should be found to be less, in the light of further information, the following figures should be corrected in accordance therewith.

RELATIVE CARRYING CAPACITY OF WROUGHT-IRON CEMENT-LINED AND CAST-IRON PIPE.

The relative carrying capacity of wrought-iron cement-lined and cast-iron pipes, based upon the above stated coefficients of discharge ($c = 120$ for wrought-iron cement-lined pipe; $c = 130$ for new cast-iron pipe; $c = 100$ for old cast-iron pipe) as applied to the Hazen and Williams hydraulic formula, *is shown by the direct ratio between the assumed coefficients of discharge;* that is, upon the above assumptions, new cast-iron pipe will discharge one twelfth more than wrought-iron cement-lined pipe under equal heads, and old cast-iron pipe will discharge but ten twelfths as much as cement-lined pipe under like heads.

Or, to put the matter in a different way, the same discharge can be had in cast-iron and wrought-iron cement-lined pipes of like diameter with the different friction losses shown in the following tabulation:

COMPARATIVE FRICTION LOSSES IN CEMENT-LINED PIPE AND IN NEW AND OLD CAST-IRON PIPE.

Internal Diameter of Pipe.	Velocity in Feet per Second.	Discharge in Gallons per 24 Hours.	Friction Loss in Feet.					
			Cement-Lined Pipe. $C = 120$.*		New Cast-Iron Pipe. $C = 130$.*		Old Cast-Iron Pipe. $C = 100$.*	
			Per 1,000 Feet.	Per Mile.	Per 1,000 Feet.	Per Mile.	Per 1,000 Feet	Per Mile.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8-inch	1	226 000	0.6	3	0.55	3	0.96	5
	3	677 000	4.5	24	4.2	22	7.3	39
	5	1 127 000	11.6	61	10.8	57	18.9	100
12-inch	1	508 000	0.43	2	0.37	2	0.6	3
	3	1 523 000	3.3	17	2.8	15	4.6	24
	5	2 538 000	8.4	44	7.2	38	11.8	62
16-inch	1	902 000	0.31	2	0.26	1	0.42	2
	3	2 707 000	2.3	12	2.0	11	3.3	17
	5	4 512 000	6.0	32	5.2	27	8.4	44
20-inch	1	1 410 000	0.24	1	0.20	1	0.33	2
	3	4 230 000	1.8	10	1.56	8	2.5	13
	5	7 050 000	4.6	24	4.0	21	6.5	34

* For use in Hazen and Williams formula.

Or, if we figure (upon the above assumptions) the necessary diameter of an *old* cast-iron pipe system to give a discharge equal to that of a wrought-iron cement-lined pipe under like head or friction loss, we find the following approximate results, within a range of velocities of from 1 to 5 feet per second:

Internal Diameter of Wrought-Iron Cement-Lined Pipe. ($c=120$.)	Necessary Diameter of *Old* Cast-Iron Pipe for Equivalent Discharging Capacity under Equal Heads. ($c=100$.)	Increase in Diameter.
8-inch	8.8 inches	10.0%
12 „	12.8 „	10.7%
16 „	17.2 „	10.7%
20 „	21.4 „	10.7%

It appears, therefore, that under the assumed conditions (as to coefficient of discharge for use in Hazen and Williams formula, for cement-lined pipe, $c = 120$; for old cast-iron pipe, $c = 100$) the cast-iron pipe in order to have the same carrying capacity as the wrought-iron cement-lined pipe at the end of a period of twenty-five years, more or less, *must be 10 per cent. or thereabouts larger in diameter.*

The effect of this increase in diameter upon the relative cost of the pipe is discussed further on.

CEMENT LINING AS A PRESERVATIVE OF THE METAL.

Past experience with wrought-iron and steel pipes indicates the distinct superiority of the former metal for water-works pipe lines. Unfortunately, however, it is impossible at the present time to obtain wrought-iron sheets of large dimensions for conduit work. This has necessitated the use in these large mains of steel, and experience up to this time with various coatings for the steel has not been thoroughly satisfactory. This subject is beyond the limits of this paper, but it is interesting to note that experiments are now being made by the city of New York, and perhaps in other quarters, upon the feasibility of lining and encasing large steel conduits with a cement coating, in substitution for the different paints and materials used heretofore for coating steel conduits.

These latter-day developments, however, contemplate a use of the cement coating primarily for the purpose of preserving the

metal rather than for securing watertightness, and the results will be watched with great interest.

RELATIVE COST OF CEMENT-LINED AND CAST-IRON PIPE.

In the subjoined table is presented a statement of the comparative cost of cement-lined and cast-iron pipe lines. The cast-iron pipe has been figured upon the approximate ruling average price of cast-iron pipe during the last twenty-five or thirty years, to wit, $25 per 2 000 pounds. The weight of pipe used is that of the New England Water Works Association standard Class A up to and including pipes of 8 inches in diameter, and Class B for pipes of from 10 to 24 inches in diameter. While these classes are somewhat lighter than have been used in city work, they certainly afford a much higher factor of safety than that ordinarily employed in designing cement-lined pipe, and they have been successfully used in many water works for pressures up to and even in excess of 100 (to 125) pounds per square inch. The total cost per foot of the cast-iron pipe furnished and laid is shown in column 6, and for convenience there is shown in column 7 the amount which should be added to make a comparison with Class C pipe of the New England Water Works Association.

The prices quoted for the wrought-iron cement-lined pipe in the case of the Plymouth works represent the actual cost of the pipe, exclusive of administration expenses of the department, and in the other cases the contract prices at which these pipes were laid. It is hoped that others who have used pipe of this character will contribute items of cost for comparison with the table on page 68.

In general it may be said that upon the assumed basis of cost of cast-iron pipe, $25 per ton, and the assumed classification, wrought-iron cement-lined pipe does not show any material saving in cost over cast-iron pipe, even when correction is made for the difference in carrying capacity between old cast-iron pipe and cement-lined pipe as referred to previously herein. The latter fact increases the total cost of the cast-iron pipe approximately 7 per cent. above the figures shown in column 6 of the table, as appears rom the following tabulation:

COMPARATIVE COST OF WROUGHT-IRON CEMENT-LINED AND CAST-IRON PIPE LINES.

Internal Diameter, Inches.	With Cast-Iron Pipe at $25.00 per 2,000 Pounds. Costs per Foot.						With Wrought-Iron Cement-Lined Pipe. Costs per Foot.					
	N. E. W.W.A. Class.	Assumed Weight per Foot.*	Pipe Cost per Foot.	Assumed Cost of Laying.	Total Cost.	For Class C Pipe add per Foot.	Plymouth, Mass.,† 1900–1907. Pipe.	Laying.	Total.	Greensburg, Pa., 1888. Total.	Concord, Mass., 1873.	Portland, Me.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
4	A	17	$0.21	$0.25	**$0.46**	$0.01	$0.33	$0.30	$0.63	$0.51	$0.76	....
6	A	28	0.35	0.27	**0.62**	0.02	0.38	0.45	0.83	0.66	1.02	....
8	A	40	0.50	0.30	**0.80**	0.06	0.50	0.50	1.00	0.92	1.22	....
10	B	57	0.71	0.34	**1.05**	0.05	0.66	0.77	1.43	1.17	1.57	....
12	B	72	0.90	0.40	**1.30**	0.06	0.89	0.79	1.68	1.53	....	....
14	B	91	1.14	0.45	**1.59**	0.08	1.13	0.43	1.56	1.85	....	....
16	B	110	1.38	0.51	**1.89**	0.10	1.24	0.88	2.12	1.80	....	....
18	B	129	1.62	0.58	**2.20**	0.14	1.41	0.83	2.24	....	....	....
20	B	149	1.86	0.64	**2.50**	0.16	....	....	....	....	....	....
24	B	195	2.44	0.80	**3.24**	0.27	....	....	....	....	....	$2.36‡
26	..	...	....	....	....	....	....	....	....	....	....	3.87§

* Allowing excess weight of approximately 2 per cent

† Plymouth labor, $2.00 for eight hours.

‡ $3.02 equivalent 1908 price.

§ $4.37 equivalent 1908 price.

PERCENTAGE TO BE ADDED TO THE TOTAL COST OF CAST-IRON PIPE (FURNISHED AND LAID) TO COMPENSATE FOR THE ASSUMED DIFFERENCE IN CARRYING CAPACITY BETWEEN CEMENT-LINED PIPE AND OLD-CAST IRON PIPE.

Diameter Pipe.	Pipe Cost per Foot.	Total Cost per Foot.	Add 10 per Cent. to Column 2.	Resulting Total Cost per Foot.	Increase in Total Cost Per Cent.
(1)	(2)	(3)	(4)	(5)	(6)
8 inch,	$0.50	$0.80	$0.05	$0.85	5.9
12-inch,	0.90	1.30	0.09	1.39	6.9
16-inch,	1.38	1.89	0.14	2.03	7.4
20-inch,	1.86	2.50	0.19	2.69	7.6
					Say, 7.0%

If the ratio in carrying capacities of the cement-lined cast-iron pipe should be as 110 to 100, as has been found to be the case in some cement-lined supply mains, instead of as 120 to 100 as assumed above, the increase in diameter of pipe would be approximately 4 per cent. instead of 10 per cent., and the corresponding increase in total cost of pipe line in place approximately 3 per cent. instead of 7 per cent., and if the ratio should fall to 90 and 95 there would be no material difference in cost.

NECESSARY PRICE OF CAST-IRON PIPE TO MAKE COST OF CAST-IRON PIPE LINE EQUAL TO THE COST OF CEMENT-LINED PIPE LINE.

Data are lacking upon which to base a satisfactory estimate of the price per ton at which cast-iron pipe may be bought without making the cast-iron pipe line more expensive than one built of cement-lined pipe, even with due allowance for greater loss in carrying capacity with lapse of time. It seems probable, however, that this price must exceed $27 to $30 per ton of 2 000 pounds, and still leave the balance as regards reliability in favor of cast-iron pipe; while the average price of cast-iron pipe during the past twenty-five years, more or less, has been approximately $25 per ton.

AVERAGE PRICE OF CAST-IRON PIPE DURING THE LAST TWENTY-FIVE OR MORE YEARS.

It was stated above that the average price of cast-iron pipe for water-works uses during the past twenty-five or more years had been approximately $25 per net ton of 2 000 pounds. In this

connection the following figures may be of interest. It should be noted also that when cast-iron pipe is unreasonably high, extension work is usually undertaken only so far as is absolutely essential. For this reason, it is not fair to average the ruling prices of cast-iron pipe from year to year to determine the average cost of cast-iron pipe to water-works departments during any period of years. The actual average cost of all pipe bought is almost certain to be considerably less than the average ruling price of cast-iron pipe over a like period of years.

Boston, Mass. During the past thirty years covering a period from 1878 to 1907, inclusive, the city of Boston awarded contracts for cast-iron pipe amounting to 115 452 short tons, aggregating an approximate cost of $2 845 670. This is equivalent to an *average price* of $24.65 per ton of 2 000 pounds.

Portland, Me. The Portland and Standish Water Companies, supplying the city of Portland and environs, purchased in the thirty-nine year period from 1869 to 1907, both inclusive, a total of 19 105 net tons of pipe, at a total cost of approximately $484 270. This is equivalent to an average price of $25.35 per ton of 2 000 pounds.

St. Louis, Mo. From the statistics relating to the " prices paid for cast-iron pipe by St. Louis, Mo., during twenty years, compiled by Wm. H. Bryan, from data furnished by W. E. Rolfe, of the St. Louis Water Department," published in the *Municipal Journal and Engineer* of ——, 1908, have been obtained the following figures: total purchase of pipe, 128 269 tons of 2 000 pounds; approximate cost, $3 034 000, or an *average price per ton* during this *nineteen-year period* of $23.74. (Inasmuch as the quantities purchased during the year 1888 were not stated, it was impossible to determine the average price for twenty years.)

Providence, R. I. The average price paid by a water company in the vicinity of Providence, R. I., covering 1 826 tons of cast-iron pipe bought in the twenty-year period from 1886 to 1906, was *$25.43 per ton of 2 000 pounds.*

Chicago, Ill. The writer is unfortunately not able to give the actual average price paid by Chicago, but the following figures for the pipe purchased during the twelve-year period from 1885 to 1906 may be of some interest:

Year.	Total Miles.	Cost Cast-Iron Pipe (2000 Lbs.).
1895	1 612.3	$26.00
1896	1 691.2	23.00
1897	1 730.3	19.00
1898	1 801.2	25.00
1899	1 846.9	25.50
1900	1 872.0	25.50
1901	1 890.0	23.50
1902	1 918.7	28.00
1903	1 939.7	33.00
1904	1 978.2	30.00
1905	2 038.5	27.50
1906	2 073.2	30.00

(Quoted from *Engineering-Contracting*, July 24, 1908.)

SUMMARY OF CONCLUSIONS.

With due allowance for variation in individual cases, and the local conditions or circumstances surrounding them, the following conclusions seem justified:

1. *Advantages of cement-lined pipe as compared with cast-iron pipe.*

a. Freedom from tuberculation and resulting maintenance of carrying capacity.

b. Carrying capacity probably approximately that of cast-iron pipe fifteen to twenty-five years old. The coefficient of discharge to be used in the Hazen and Williams formula probably lies between $c = 100$ and $c = 120$, depending upon the care used in making the pipe and the excellence of its finish.

c. Longevity and durability under *favorable* circumstances.

d. The cost may show some advantage when cast-iron pipe reaches a price upwards of $27 to $30 per ton.

2. *Disadvantages of cement-lined pipe as compared with cast-iron pipe.*

a. Absolutely and relatively greater dependence upon good material and good work in all details of manufacture and laying of pipe.

b. Greater danger of bad or slipshod work in wet trenches and under conditions affording insecure foundations.

c. Greater cost under average market conditions.

d. Unreliability and danger from subsequent excavations adjacent to pipe line.

e. Small factor of safety and consequent danger from water hammer, careless manipulation of gates, etc. (The usual factor of safety of wrought-iron cement-lined pipes has been from 3 to 4; in steel pipes from 4 to 5, and in cast-iron pipes from 12 to 15, but the greater ductility of wrought-iron or steel as compared with cast-iron should be borne in mind in this comparison.)

f. Resulting comparatively low limit of safe pressures, 65 pounds per square inch, more or less.

g. The carrying capacity may not differ materially from that of old cast-iron pipe if the cement-lined pipe is badly made or laid, or is considerably smaller in actual than in nominal internal diameter.

h. Danger from lightning and liability of more extended damage from it.

i. Difficulty in making watertight joints and connections.

j. Repairs not so easily, cheaply, quickly, or effectively made as for cast-iron pipe.

k. Difficulty in making service pipe connections and greater likelihood of leakage.

3. Satisfactory data are lacking upon the carrying capacity of cement-lined pipes. It is believed that under favorable conditions the coefficient of discharge to be used in the Hazen and Williams formula is about $c = 120$, but under actual conditions this coefficient has been found, in several carefully observed cases, to lie between 95 and 110. Unless the conditions are definitely known, therefore, the use of a coefficient not exceeding $c = 100$ to $c = 110$ in the Hazen and Williams formula is recommended.

4. The relative carrying capacity of wrought-iron cement-lined pipe, new cast-iron pipe, and old cast-iron pipe, based upon assumed coefficients of discharge (for use in the Hazen and Williams formula) is in proportion to these coefficients of discharge:

$c=120$ for wrought-iron cement-lined pipe. (A safer figure would be $c=100$ to $c=110$.)
$c=130$ for new cast-iron pipe.
$c=100$ for old cast-iron pipe.

5. The comparative frictional losses based upon these assumptions are shown in the tabulation on page 65.

6. Upon the above assumptions the necessary increase in diameter of a cast-iron pipe line over that of a wrought-iron cement-lined pipe line that it may have the same discharging capacity at the end of a period of twenty-five years, more or less, should be approximately 10 per cent. If, however, the relative coefficients of discharge for cement-lined pipe, as compared with cast-iron pipe, are as 110 to 100 instead of 120 to 100, the necessary increase in diameter would be approximately 4 per cent.

7. The additional cost involved by the above-mentioned necessary increase in diameter of cast-iron pipe over cement-lined pipe, that they may have the same carrying capacity after a long period of years (based upon assumed relative coefficients of 120 for cement-lined and 100 for old cast-iron pipe), is approximately 7 per cent. If, however, the relative coefficients are as 110 to 100, the increase in cost would be but 3 per cent.

8. The cost of wrought-iron cement-lined pipe as compared with cast-iron pipe does not appear to be materially different and is slightly in favor of the cast-iron pipe up to diameters of 20 inches, more or less,— if a comparison be made upon the basis of use of classes A and B, Standard Specifications for Cast-Iron Pipe of the New England Water Works Association, which in the opinion of the writer is certainly as reliable as, and probably more reliable than, wrought-iron cement-lined pipe of the type heretofore used.

9. For purposes of comparison it seems reasonable to use an average price for cast-iron pipe of $25 per net ton of 2 000 pounds, inasmuch as this figure seems to approximate the average cost of cast-iron pipe for a period of twenty-five or more years in the past.

10. While it is true that many wrought-iron cement-lined pipe systems, built between the years 1870 and 1880 or thereabouts, are still in use, general experience seems to show that abandonment has begun within a period of twenty or twenty-five years after construction, though it is probably fair to say that this abandonment may have been due in some measure to the gradual increase in water pressures demanded of our water works by the change in height of buildings and the improved standards required

for fire protection. Certainly the general use of cement-lined pipe for water works purposes has been given up.

11. The average annual cost of making repairs to wrought-iron cement-lined pipe appears to have been as low as $10 per mile of pipe under favorable circumstances, and as high as $50 per mile of pipe, or even more, under less favorable circumstances.

12. Damage from lightning appears to have been a source of considerable expense in making repairs. The cost of these repairs is covered, however, in the above figures of annual cost of repairs per mile of pipe.

GENERAL CONCLUSION.

In conclusion, therefore, the writer is of the opinion that broadly speaking, it may fairly be said that:

1. Experience in this country with wrought-iron cement-lined pipe systems *for distribution purposes* has in general been adverse and has led to its replacement with cast-iron pipe,— except, perhaps, under conditions where the pressure does not materially exceed sixty-five pounds per square inch, and where there has been but little disturbance of the ground adjacent to the pipe trench which might cause settlement or other injury to the pipe line.

2. Experience in this country with wrought-iron cement-lined pipe systems *for supply mains* has been much more satisfactory than for pipe distribution systems, and many old wrought-iron cement-lined supply mains are still in active use and giving satisfactory and economical service, particularly under such conditions as are usual in the case of these supply mains,— light pressure, secure foundation, and private rights of way within which the pipes are located, resulting in little danger of disturbance.

3. It is still possible that economical means will hereafter be developed for lining steel or even cast-iron pipe in a similar manner to that so successfully now employed in lining service pipes with cement, which will result in a better pipe than any yet used. But such use of cement is likely to be limited to furnishing a durable coating rather than watertightness and added strength to the pipe.

The writer takes this opportunity of expressing his obligations to the various superintendents and other officials or employees

of the water works, who have so courteously and willingly contributed much of the information contained herein, without which this article would have been impossible.

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DISCUSSION.

MR. ARTHUR E. BLACKMER.* I don't think there is very much that I can add to what Mr. Metcalf has said. It is a fact that we have comparatively little trouble with our cement-lined pipe. We have about fifty miles in use now in sizes from four up to

* Superintendent Water Works, Plymouth, Mass.

eighteen inches, possibly half of which, or a little less, is of the old style of pipe, the Goodhue & Birnie, and approximately one half of the new Phipps patent, so-called. The pipe gives us practically no trouble under our pressures, which range from about thirty up to about seventy pounds as the maximum. We make the regular cement joint with a male and female ring and a sleeve, and our service-pipe connections are made by tapping in the corporations, and those, also, have been, so far, a source of very little trouble and expense. Down in Plymouth we look upon this pipe very favorably, though I am aware that it is not so regarded in most waterworks communities. I don't know that I have anything more to say, but if there are any questions to be asked, I will be very glad to answer them if I can.

MR. ROBERT S. WESTON.* I would like to ask Mr. Metcalf or Mr. Blackmer if slime molds have ever been observed on the inside of the cement-lined pipe, which would have a tendency to reduce the discharge. I know that they occur within cement pipes and masonry conduits.

MR. BLACKMER. I have never discovered anything of that sort. We had occasion, recently, to take out a few lengths of 10-inch pipe, which have been in use since 1855, I think, and apparently they were as clean as when they were put in. There is one point in regard to Mr. Metcalf's coefficient of carrying capacity of the 10-inch pipe to which I should like to call attention, and that is that the pipe was an old pipe laid in 1855 and not one of the new style pipes.

MR. METCALF. In answer to Mr. Weston, I would say that I have seen evidence in two or three cases, certainly, of some growth of the sort he mentions on the pipe; but more often I have found the pipe, in the pieces which have been take out in cutting in hydrants or valves, or for one reason or another, substantially free from anything of that sort.

MR. E. W. KENT.† I would like to ask Mr. Blackmer one question with reference to the table on page 68, column 9, where there seems to be a surprising difference in the cost of laying the pipe, a 6-inch pipe costing 45 cents a foot, and a 4-inch, 30 cents.

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* Sanitary Expert, Boston, Mass.

† Engineer and General Superintendent, Water Works, Newport, R. I.

MR. BLACKMER. That column was prepared by a clerk in the office. The cost of the 6-inch was an average of two lines which were unusually expensive lines to lay. They were laid rather deep, and we had a good deal of trouble with the main sewer, and a whole lot of trouble which increased the expense. That is not a fair average cost of the 6-inch line; it is too high.

MR. R. C. P. COGGESHALL.* I should like to ask Mr. Metcalf a question. We had originally about eight miles of cement pipe in our city, which was very poorly laid, and we used to have frequent breaks. Some years ago there was a remnant of it left, and at that time, when the electrolysis problem was coming up, I remember that Mr. Knudson, who made the examination in New Bedford, pointed at once to that remnant of the cement pipe and advised us to get it out as quickly as we could, saying that it was a good deal more liable to damage by electrolysis than cast-iron pipe. Now I would like to ask Mr. Metcalf if in the light of present knowledge, that is considered to be absolutely true.

MR. METCALF. You have asked me a very difficult question, Mr. Coggeshall, and I cannot answer you directly, because that question ought to be answered from experience and I do not think our present information is sufficiently definite to enable us to say whether that is true or not.

In discussing that very point with one of our prominent engineers who is laying some large steel mains at the present time, and is planning to coat them with cement for a portion of their length, partly on that account, he seemed to feel that the chances of trouble were less than with cast-iron mains. You have a good conductor throughout the entire length, and if the current gets on to the pipe it doesn't leave it at the joint and get on again. The trouble from electrolysis in a pipe line comes at the point where the current leaves the pipe; and in his case the question was as to whether he should make at certain points good connections for the current to leave the pipe, or whether he should simply take his chances on that and try to keep the pipe as dry as possible.

At the present time it seems to me that about all we can say is that the trouble from electrolysis is likely to be minimized if you can keep the pipe, in running it through the fields, dry rather than

* Superintendent Water Works, New Bedford, Mass.

in a moist condition, particularly in soils which carry a large amount of organic matter. Of course if you can get real wrought iron in place of steel you will find it more desirable, but the difficulty is that for these large pipes you cannot get large wrought-iron sheets; they are not manufactured. I think you can lay a 20-inch line, perhaps, of wrought-iron pipe; I do not think you can get a 30-inch without increasing the cost very seriously and the amount of riveting very largely.

MR. FRANK L. FULLER.* In cutting out some pipe at Winthrop to examine the pipe system we found that some of the pipes, in fact, I think all of them, had a coating of slime on the interior surface, and in that slime there were what you might call "wigglers," perhaps very small, something like what we find in stagnant water as the first stage of the mosquito. I have never seen them anywhere else and I didn't know whether they were peculiar to that system of piping or not. The pipe seemed to be in very good shape. A good deal of it had been laid quite a number of years, and as a general thing it was in very good shape and the interior was quite smooth.

THE PRESIDENT. In partial reply to what Mr. Coggeshall has just asked, I would say that in Springfield we have had more trouble from electrolysis on service pipes attached to an old cement-lined pipe than anywhere else, but I had always supposed that the reason for that was because that pipe is in a street quite near to the power station, so that the current follows it in coming back to the generating source.

MR. METCALF. Is not that perhaps some evidence that the cement coating protected the wrought iron?

THE PRESIDENT. Very likely, and the current left the service pipes. In some cases it had eaten up the corporation cocks entirely, so that we had to put a sleeve over the pipe to repair it.

MR. LEONARD C. ROBINSON.† We have about twenty miles of cement pipe mains. In 1905 there was a call for a high service for better fire protection, and it was decided to subject the wrought-iron and cement-lined mains to a series of hydraulic tests. A portable outfit was obtained, consisting of a single-acting Knowles

* Civil Engineer, Boston, Mass.

† Superintendent Water and Sewer Department, Concord, Mass.

pump 10 x 12 and steam boiler on rollers, and the mains were cut out section by section and then subjected to a test of from three quarters of an hour to an hour's steady pumping with a pressure of from eighty-five to one hundred pounds. Altogether there have been a little over twelve miles subjected to those tests. There have been 40 tests of pipe, and during that testing there were 25 leaks developed. The greater part of the leaks were on the 4-inch mains. Less than a mile of 8-inch pipe has been tested, and about two miles of 6-inch and something like nine miles of 4-inch pipe. The cause of the breaks in almost all cases was the detaching of the cement from the shell. Some ten years ago a system of sewers was installed in the center of the town, and a great deal of trouble with the pipe was caused by the settling of the pipe and the cement coating cracking and then the iron rusting. In one place three lengths were taken out where the pipe had settled so that the cement coating on the under side was entirely detached from the shell.

In the portion where there has been very little or no excavation in the streets, which comprises nearly one third of the length tested, there was only one break. Our pressure is comparatively light, something like forty-three pounds. The high-service system is now being installed, and the pressure will be increased to something like one hundred pounds, as Mr. Metcalf has spoken of, in times of fire. The original works were laid in 1874, and extensions were made with cement-lined pipe up to and including 1888. There was practically no difference in the number of breaks we got on the old mains and on the more recently laid.

Mr. Robert S. Weston. I would like to add a word regarding the theoretical considerations concerning electrolysis. It isn't the electricity which decomposes and dissolves the iron, but it is the products caused by the passage of electricity through something. Now from the purely theoretical standpoint it would be inconceivable to believe that electricity passing through the soluble products, or the dissolved part, of a cement coating, could attack iron, because all of the products which would be produced by electrolysis would preserve rather than attack the iron. On the other hand, of course, electricity passing from the pipe through water would decompose it into elements which would

attack the iron, especially in passing from iron through an acid soil, or through a soil containing a good deal of acid organic matter. It would seem that the conditions which affect the electrolysis of cement-lined pipe would be entirely independent of the cement coating, or else, if they did come in at all, they would act as protective agents rather than destructive influences.

THE PRESIDENT. Some of the most serious breaks we have had in Springfield since I have been connected with the works have been on this old-fashioned kind of cement-lined pipe, and we are now engaged in removing it as fast as we can. This year we have taken out some four or five miles of it, and next year probably as much more will be taken out, and so we shall go on until we have it all finally eliminated from the system. Practically the reason for doing it is that we are now engaged in remodeling our distribution system, and when that is finished we shall have only one service, which will be a high-pressure service. We now have two services, a high and a low pressure; the low-service system gives us about forty pounds pressure, and the new high-service system will carry about one hundred and forty pounds in the low districts and eighty pounds in the higher parts of the city.

One of the worst breaks we ever had was on a 12-inch cement-lined pipe, a little less than a year ago, in January, one of the most bitter cold mornings we had last winter. The department was called out at about five o'clock in the morning to shut off the street. The pipe was underneath the car tracks, and the water had followed along under the frost, which was about eighteen inches thick, to a point where it appeared about four or five hundred feet from where the break was; but before we could get the street entirely shut off the water succeeded in forcing its way up right over the break. We went to work immediately to repair the break, but it took us three days to repair the street for that four or five hundred feet in length, on account of the frost, and the car track was torn up so that cars couldn't run over it during that time. We got the pipe itself repaired in the course of twenty-four hours. We had to take out one whole length, of course, 7 feet, and put in another, and then when we turned the water on the next length had to come out of the ground just the same way. There were about eighteen hours of good solid work on one of the most

bitter cold days of last winter repairing a cement-lined pipe, and you can judge from that whether I should be in favor of installing cement-lined pipe in any system.

MR. JOHN C. CHASE.* Mr. Metcalf's very exhaustive paper has left but little to be said. I trust he will not take serious offense, however, if I intimate that in my opinion what he has said will have very little weight in regard to the use or non-use of the pipe in the future. In a place where they have had the successful experience that they have had in Plymouth, I hardly think they would be strengthened in their belief in cement-lined pipe; but I doubt very much whether Plymouth's experience or anything which could possibly be said, would lead our friend Walker to lay another foot of cement-lined pipe. "Ephraim is joined to his idols; let him alone."

The high price of cast iron in the period from 1870 to 1875 was the cause of the boom, if I may use that term, in the use of a sheet-metal pipe. If the pipe had been properly, intelligently, and conscientiously laid, its life would have been a great deal longer, and it would have stood in great deal better favor with water-works people. I think the source of trouble with cement-lined pipe has been the fact that whenever it was laid by contract it was slighted wherever it could be. To give an idea of how quickly it began to come into disfavor, the city of Manchester, N. H., laid some forty miles, I think, in the period from 1871 to 1875, but abandoned its use as early as 1877.

Structurally I know of no reason why a sheet-metal, cement-lined pipe cannot be made that will answer all purposes and be entirely satisfactory, but it would be a pretty costly pipe to lay, and with the price of cast iron as it is at present and prospectively, the margin of difference would be such that it is a question whether it would be desirable to lay cast iron to make up for the expected lack or decrease in carrying capacity. And, as Mr. Dooley says, "There ye are."

MR. JASPER A. FITCH.† Cement-lined pipe seems to be getting the black eye here, Mr. President. I haven't got much to say about it, but I am interested in a small plant in Manchester,

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† Superintendent Water Company, Manchester, Conn.

Conn., owned by the Manchester Water Company, and we haven't anything but cement-lined pipe there. Our pressure through the main village is about seventy pounds, and we have about twelve miles of pipe, — a small plant. In three or four miles of that there is a pressure varying from 70 pounds to 100 pounds, and we are having very little trouble. The plant was established in 1889, the pipe has been in a little over nineteen years, and we have but very little trouble from breaks or joints. Sometimes we go through a year and there isn't a break at all, but occasionally we have a break the same as we would with iron pipe.

Our pipes are running in streets close by the trolley line, in some cases under it, but we never have had any trouble from electrolysis excepting in a case where an iron service pipe ran under the car tracks. In several cases we have had the iron service pipe eaten out by electrolysis, and it has had to be replaced, but there has been no trouble on the cement-lined pipe at all. We have had two cases where the gooseneck of brass was affected by electrolysis. As I say, our experience is not so great as that of some of you gentlemen, and we haven't got so many miles of pipe, and it hasn't been in so long, but we are well pleased with the working of it in our system.

Mr. J. C. Hammond, Jr.* Mr. Fitch is a neighbor of mine,— our towns join,— but our experience has been a little different. Our first aqueduct was laid in 1847 with cement pipe. We woke up along in 1866, and since then we have laid nothing but cast-iron pipe. That was before the days of the trolley, and I don't know much about the effect of electrolysis, but I know that when the current from the power house gets into a cement pipe it will go the whole length of it. I would recommend from my experience cement pipe for lightning rods, and for nothing else.

Mr. Edward V. French.† Mr. Metcalf has mentioned in his report some experience in Lynn, and I might just add a word bringing that up to date. We have taken out something over seven miles of cement pipe in the distribution system. There are plenty of breaks in it; it is something over twenty years old, I think all of it, and is giving us trouble regularly, so we are replacing it just as rapidly as possible. There are about seventeen miles

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† Vice-President and Engineer, Arkwright Mutual Fire Insurance Company, Boston.

left, which we hope to get out in the next few years. The pipe from some of the ponds down to the pumping station, running under a moderate head, perhaps less than fifty feet, has been in service for a great many years, and gives no trouble whatever,—following well the conclusions which Mr. Metcalf reaches.

We had one break this last summer in a 6-inch cement pipe, which tore up the street and threw large stones and a good deal of gravel up into the second and third stories of an adjoining tenement building, nearly covering up some of the people as they slept, and doing damage which cost the water department perhaps $1,500 to $1,800. So in Lynn, anyway, there is no more cement pipe going in at present.

THE PRESIDENT. Perhaps I ought to have said, in connection with our experience in Springfield, that we have a 24-inch cement main pipe from our reservoir to the city, about twelve miles, and that main gives us less trouble than any cast-iron pipe we have in the city. We have had but one or two leaks on it since I have been connected with the works. So perhaps I ought to be on the fence as to whether to use cement-lined pipe or not.

I also ought to have said that the break I mentioned showed a good deal of evidence of electrolysis. There wasn't enough so that we could charge it to the railroad company. They presented us a bill for repairing their tracks, but the bill hasn't been paid yet and they haven't tried to enforce it, so I think it is perhaps just about six one way and half a dozen the other.

MR. EDWIN C. BROOKS. In regard to what Mr. Metcalf said concerning cement being a protection against electrolysis, I would say that we have a great deal of electrolysis on service pipes, and that it occurs more frequently than anywhere else under conduits carrying feed wires.

MR. DEAN. I notice in the summary there is reference made two or three times to the use of cement-lined pipe in this country. I would like to ask whether cement-lined pipe is used in any other country.

MR. METCALF. I am not informed, Mr. Dean; I don't know what the experience abroad is.

A MEMBER. I would like to ask Mr. Blackmer or Mr. Metcalf what protects the pipe on a pump main. I have noticed

where the outside coating has been cut off that you will see it throb like a person breathing. What protects that pipe to keep the thin iron from rusting? The first time I noticed it was down in Mr. Blackmer's town, on a 16-inch main, I think it was, right close to pumping station. I remember I was making a connection for them, and I had a date in another town for that evening, and when they started up the pump to see whether it was all right, and I saw this throbbing, I thought I was done for. I don't know how long it lasted, but you could see every stroke of the pump on the shell, where the outside coating was taken off.

MR. BLACKMER. I don't know as I quite get the question. The new main has been laid only about a year, and some of the time there is direct pumping, but we haven't had any trouble whatever with it; we haven't had any leak to repair. I would like to ask Mr. Metcalf if he knows whether most of the data he has collected with regard to leaks and the cost of repairs, etc., are on the old style of Goodhue & Birnie pipe, or whether any of the data are on the newer style Phipps patent. I think it makes quite a little difference in the cost of maintenance and repairs what style of pipe has been installed.

MR. METCALF. Answering Mr. Blackmer's question, I think it is a fact — I don't know that I can state it absolutely as a fact, but I believe it to be a fact — that the leakage has been greater on the Goodhue & Birnie pipe than on the Phipps pipe, for the obvious reason that in the Phipps pipe the outer coating of cement is protected from injury in transportation and laying by this outer covering of steel or wrought iron, as the case may be, and by the fact that you are more likely on this account to get a substantial thickness of cement outside of your pipe at all points than you are in the case of the Goodhue & Birnie pipe, in which the casing or coating of cement is formed in the trench itself.

As to the question raised by the previous speaker, I take it that what he refers to is the breathing of the pipe, which I presume to be due to the surge of the water in the pipe line. That you would have in the case of wrought-iron cement-lined pipe in the same way that you would in the case of iron pipe or steel pipe. As to whether it would be sufficient to rupture the cement covering of the pipe or not, I suppose would depend upon its magnitude. I

should think you would be less likely to have serious trouble from it, perhaps, with a cement-coated pipe than with a steel pipe, — perhaps not less trouble, however, than you would have with a cast-iron pipe.

The effect of surge upon the pipe was referred to by Mr. Hazen a few days ago in speaking to me of some tests which he had just observed upon lock-bar pipe and riveted pipe. I think the lock-bar pipe had been put under 750 pounds pressure per square inch and had been tight. The riveted pipe had been put under a very high pressure,— I am not sure that it was over five hundred pounds, but it was very substantial pressure. Up to a certain point Mr. Hazen said the pipe was perfectly tight, but a few added pounds made it leak all the way along under the rivet heads and along the seams, so that the water simply poured out; it more than seeped out; it ran out of the joints. Yet, when that pressure was released, or reduced to a slightly lower point, the pipe was tight again. Mr. Hazen said it almost led one to believe that a riveted pipe of that sort furnished its own safety valve in long mains, so that when the pressure got intolerable, the pipe would open and let the water out.

Mr. Caldwell. May I say a word in answer to Mr. Dean's question? I think I can speak for the provinces of Ontario and Quebec, for I have covered that territory pretty thoroughly, and I do not know of their using any cement-lined pipe for mains in either of those provinces.

W. H. Richards (*by letter*).* If Mr. Metcalf's paper should encourage the use of cement-lined mains in any place where the conditions of a modern city prevail, except where some rare quality in the water precluded the use of cast iron, it would be most unfortunate.

The use of cement-lined pipe in large quantities prevailed about 1870 for reasons of economy (cast iron being very high). On this ground about twenty-three miles was laid under the direction of the writer between 1872 and 1884. While the number of leaks per mile was not excessive, the cost of repairing them, owing to their nature and the damage occasioned, was very great and is not indicated by their number. This pipe has been removed with the

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exception of 8 miles, and the cost of repairs per mile has dropped from $30.00 to $9.00.

The causes of failure in cement-lined pipe as observed by the writer were:

1. Lack of tightness of the shell. The porosity of the lining allows moisture to pass through to the shell, and, unless the shell is tight, to pass under the outside coating where the water, together with the air, corrodes the shell from the outside. This was overcome, and at the same time the strength was greatly increased, by using spiral riveted shells, the seams of which were filled with liquid wood pulp under pressure, after which the shell was dipped in asphalt and then lined with cement mortar made of carefully selected materials. Pipe constructed in this manner in 1883 is now in as good condition as when laid. Its cost, however, is much higher than cast iron.

2. Lack of strength to resist water-ram, etc. This was overcome as above, but at great cost.

3. Rigidity of joint which admits of no settlement.

4. Liability to injury from street excavation.

The first and second objections can be overcome by a large increase in cost and with no corresponding advantage over cast iron except in the rare cases where the nature of the water makes corrosion excessive.

It is impossible to attain even partial success with cement-lined mains without the most careful and painstaking inspection of the process of manufacture and the materials entering into it, and, as before stated, there is no corresponding advantage gained over cast iron.

In streets where excavations are freqeunt, as is the case in all of the larger towns and cities, cement-lined mains are entirely unsuitable.

I think that any manager of water works who has had twenty or more years of experience with cement-lined pipes and has kept out of an insane asylum will endorse my views.

MR. FRANK A. BARBOUR (*by letter*).* I have had no experience in laying cement-lined pipe, but have had considerable opportunity to investigate its condition after use of twenty years or more.

* Civil Engineer, Boston, Mass.

At the present time there are in Peabody about thirty miles of cement-lined pipe, varying in size from four to twelve inches in diameter. In 1895 there were thirty breaks, in 1905 sixty-five breaks, with a gradual increase between these years, while in 1906 and 1907, owing to the construction of sewers, the number of breaks rose to much higher figures. But little trouble has occurred at joints, the cause of breaks being generally corrosion from the outside. The leakage through this old cement-lined pipe is large and when the water pressure was raised 20 pounds, in 1904, the amount lost through the mains increased 200 000 gallons per day.

In Woburn, at the present time, there are about forty-five miles of cement-lined pipe, perhaps more than in any other place in this state. Recently an opportunity was afforded the writer to make an examination of this system for leakage, which has gradually increased to a point where it constitutes a large element in the cost of operation and is the principal cause of the present necessity for an increased supply. The leakage in the distribution system was studied by isolating small sections and measuring, by a meter, placed in a hose line stretched from a hydrant outside the district under examination to another hydrant inside this district, the water wasted either from the mains or by defective plumbing between the hours of 12 midnight and 4 A.M. If an abnormal quantity entered the isolated section, one street after another was shut off until the principal cause of the waste was located. To separate leakage from mains and from bad plumbing, the services in some cases were also shut off. In this way it was found that 90 per cent. of the leakage was located in 19 miles of the distribution system, the other 26 miles being in comparatively good condition. The greater part of the loss of water occurs in the smaller sized pipes — in one case a leakage of 100 000 gallons per twenty-four hours being found in 4 000 feet of 4-inch pipe. This is probably explained by the fact that lightning, to which most of the breaks in Woburn are attributed, has a greater effect on small than on large pipe, the larger pipe, apparently, because of the greater sectional metal, being capable of carrying off the electric charge with less disastrous results. The grounding of telephone wires on the service pipes is believed to add to the trouble due to lightning.

However, leakage is not confined to the smaller sizes, and in some sections of 12-inch pipe a loss equivalent to five or six gallons per linear foot was found. This might hold good for a certain length, while the next section of the same pipe would prove to be watertight. The explanation may lie in the varying character of the work originally done under different foreman, or to the effect of sewers subsequently constructed near the water pipes.

The depreciation of the cement-lined system in Woburn has reached the point where comprehensive replacement with cast iron must be undertaken in the near future, a fact which constitutes an interesting commentary on cement-lined pipe in general. In 1890 the superintendent of the Woburn works presented a paper to this Association extolling the merits of this type of conduit and claiming for it superiority over cast iron. The pipe had then been laid seventeen years and was considered entirely satisfactory by him. From the reports of the Water Department it appears that in 1890 there were 23 breaks; in 1894, 25 breaks; in 1896, 68 breaks (due to sewer construction); in 1900, 50 breaks; in 1905, 53 breaks; in 1906, 59 breaks; in 1907, 44 breaks; and in 1908, 71 breaks. Of the 50 breaks in 1900, 18 were charged to rust holes, 12 to joint leaks, and 13 to thin lining, 90 per cent. being on the 4- and 6-inch pipe. Of the 53 breaks in 1905, 29 are attributed to lightning, 11 to thin lining, 5 to rust, 3 to shutting hydrants too quickly, and 5 to joint leaks, again 90 per cent. being in the 4- and 6-inch pipe. It is evident that, after a use of twenty years, depreciation in Woburn became rapid, particularly since the date of installing the sewers.

Whether this class of pipe is subject to depreciation by electrolysis is perhaps debatable, but in Peabody, on those streets where the service pipes have been most rapidly eaten away by electrolytic action, the cement mains have on the outside the characteristic pitted appearance which such action develops in cast-iron mains, and such appearance is most marked on those streets where electric car tracks are located.

In the majority of breaks which the speaker has examined, the iron has been weakened by corrosion from the outside, the result of uneven placing of the outside layer of mortar, subsequent cracking of this layer, or too much sand in the mortar. In many

cases, however, breaks occur at points where in lining the pipe the cone has not been properly centered and the lining is consequently thin on one side. At these places scaling occurs and the exposed iron is reduced by rust until it cannot withstand the pressure.

Such disabilities as unevenness of covering of cement inside or out, too much sand in the mixture, or injury of the outside layer in laying are matters of workmanship rather than the unavoidable conditions necessarily incidental to this type of pipe. In such causes lies the explanation of the failure of much of the cement pipe laid thirty or forty years ago, but it is well to note that this cause of failure can be overcome, to some degree, by better workmanship — a result which has doubtless been accomplished in the more recent pipe of this type such as is used in Plymouth. In this respect, therefore, a fair criticism of this type of pipe is that for good results such care in manufacture and laying is required and such a cost necessary as compared with cast iron that under ordinary conditions it is neither economical nor worth while undertaking the responsibility of its installation.

Regardless of workmanship, however, there are faults inherent in this type of conduit which precludes its general use in distribution systems. The effects of lightning, the inability of the inelastic cement covering to accommodate itself to the continued pulsation of pumps, or abnormal water hammer in closing the hydrants, the inevitable injury to such pipe by the slightest movement of the ground during the construction of sewers, the liability to injury of the cement lining in tapping for service pipes, the gradually increasing leakage with the resulting cost in pumping system — all discount its use in distribution work. Whether gravity mains under light pressure with no service or hydrant connections may justifiably be laid with cement-lined pipe is largely a question of relative economy. I, therefore, agree with the author of the paper that if such pipe ought to be used at all its place is only for gravity supply mains and not in the distribution system.

The Association is to be congratulated on the comprehensive work done by Mr. Metcalf in making available for ready reference so much information in regard to cement-lined pipe. The paper is of value, however, as an historic record rather than in the possibility that much of this type of conduit will be used in the future.

THE WATER SUPPLIES OF NEW YORK STATE.

BY H. D. PEASE, M.D., DIRECTOR STATE HYGIENIC LABORATORY, ALBANY, N. Y.

[*Read November 11, 1908.*]

To visit one's native city is always interesting. When that city is Boston it becomes a feeling of stimulation and of pride; but to return and talk of one's work before an active and honored body of co-workers, such as the New England Water Works Association, should be the acme of satisfaction.

In talking to you of the water supplies of New York State I shall be obliged to limit the discussion to such aspects of the subject as have come particularly under the notice of the State Department of Health, and this will perforce exclude many matters of undoubted interest to you.

Thus I am not in a position to discuss the great work now being conducted in New York State towards the further development of the water supply of New York City. The problems involved in the construction and maintenance of the series of great public works, comprising the various water supply systems of New York City, are of such magnitude that they naturally exclude themselves from the consideration of a comparatively small department of state government, only a part of whose work lies in a similar direction.

I wish to discuss first the proper scope of the work of a state department or board of health in relation to the water supplies of its various political subdivisions or municipalities.

It appears to me that the fact should not be lost sight of that the departments or boards in question have as the main object of their existence the protection of the public health and the prevention of avoidable disease. Such departments or boards should not, therefore, in their dealings with water supplies, be expected, nor should they endeavor, to cover the fields of civil engineering, or to assume the judicial authority of the legislature and the

courts except in so far as it becomes necessary to do so in order to fulfill their main object.

Their chief function must always remain the protection of the public health and not the development of water-works engineering, nor the allotment of sources of water supply to various municipalities. Indeed, it has always seemed from this standpoint to be a misfortune that there has developed in so few states a department or departments of state administration, whose duty in part or in whole should be the accurate survey and determination of the water supply possibilities of the state and the various uses to which they could be economically directed.

No such department or departments have existed in New York state, although portions of such work have been performed by the departments of the state geologist, of the state engineer and surveyor, and from time to time by various water storage commissions now out of existence, and more recently by the State Water Supply Commission.

The work performed by all of these departments, except the latter, has related to the geographic, physiographic, and industrial conditions of the various watersheds, while the State Water Supply Commission was brought into being in 1905 for the purpose of providing for a fair and equitable distribution of the potable water resources of the state among the various municipalities. Some of these commissions have endeavored to bolster up their reasons for existence by attempting to absorb the functions of the State Department of Health in the investigation and regulation of the sanitary quality of water supplies, but up to this date their efforts have been practically futile.

The fact that the State Board of Health was the proper state department to be placed in charge of the protection of the public water supplies of New York was recognized by the legislature as early as 1885, only three years after the organization of the board. This recognition consisted in delegating to the board authority to make rules and regulations for the protection of public water supplies and their sources in the state.

This was excellent, but there were a number of conditions attached which have tended to prevent an overpowering desire on the part of municipalities and water companies to apply for the

formulation of such rules. The law provided that practically the entire burden of the enforcement of these rules and the whole expense of any changes or alterations required under their operation should fall on the municipality or water company benefited.

In the absence of a request to formulate these rules, the State Board of Health could gain little or nothing by making them, for the law provided that the inspections of the watershed for the violations of the rules were to be made by the water board or company whose supply was being benefited, and only upon their report to the State Board of Health could the latter take action under the law, nor could the board require that inspections be made by the water board or water company. This latter feature has been corrected by a recent amendment, which gives the state commissioner of health power to order regular and special inspections to be made.

As this law now stands, the locality to be benefited must apply to the department to make the rules for the protection of their water supply; this the department does after proper investigation; the rules are then approved by the local boards of health in the districts affected by them, and are finally published in the public press; the municipality must pay for the changes required by the rules; the local water company must make regular inspections to discover any violations of the rules and must serve notice upon the violator to correct them. If the violator refuses or neglects to comply with the rules, then the State Department of Health must be notified, and the latter must make an inspection to ascertain the true facts regarding the alleged violation; if this violation is found to exist, the department must then order the board of health of the district in which the violation occurs to convene and enforce obedience. If this local health board fails to perform this duty, then any person affected by the violation, from the State Department of Health down to the humble citizen, can begin action for the recovery of the damages and the issue of a restraining injunction against the violator.

At present sixty surface supplies are protected by such rules. There are still, however, about two hundred public surface supplies in New York state not so protected. Nevertheless this does not of necessity mean that all these latter supplies are not potable

waters of good sanitary quality, for a considerable number of them are subjected to more or less efficient filtration and are not much in need of the protection afforded by the department's rules.

For the purpose of stimulating local activity toward the correction of insanitary conditions on the watersheds of these unprotected water supplies and of creating a sentiment in favor of the formulation of rules, Dr. E. H. Porter, State Commissioner of Health, has during the past two years taken action along two lines.

First, he has ordered the State Hygienic Laboratory to undertake the bacteriological and chemical examination of samples of water collected by the inspectors of the department or laboratory from as many municipal supplies and at such intervals as the laboratory's resources would permit.

Second, and more recently, there has been ordered a sanitary survey by the Division of Sanitary Engineering, of a selected list of fifty of these unprotected water sources.

Acting under these orders, we have made in the hygienic laboratory examinations of 200 municipal water supplies during the last twelve months. Of these, 59 have been examined twice; 28, three times, and 20 have been subjected to repeated examinations at irregular intervals of an average of one month.

In the majority of instances the collection of the first samples was made personally by Mr. L. M. Wachter, the chief sanitary chemist, who at the same time also made a preliminary and rather general sanitary reconnaisance of the watersheds. In this work particular attention has been paid to municipalities having a high water-borne typhoid death-rate, and to filtration systems of the various types. This work has accomplished decided results in the way of the stimulation of the local authorities to undertake the correction of conditions dangerous to health.

It was as a result of this work that the city of Poughkeepsie was led to see clearly that the winter epidemics of typhoid fever during the years 1905–6 and 1907 were due to serious structural defects and deficiencies in the management of its historic slow sand filtration system. The application of the proper remedies brought about a most decided improvement in the typhoid situation during this past winter.

The following municipalities have been influenced to a greater

or less extent to take steps toward the elimination of dangerous conditions in their water supplies by the work of the state laboratory: Cohoes, which is now planning for a proper filtration system for its Mohawk River supply; Peekskill, which has plans at hand for a slow sand filtration system; Rensselaer, which was led to make extensive corrections in its mechanical gravity filters; Elmira, which has greatly improved the operative efficiency of its filter plant; and Niagara Falls, which is planning a new supply from comparatively unpolluted portions of the Niagara River.

As soon as sufficient data has been collected regarding some of the other questionable water supplies, the department will take vigorous steps towards the creation of a proper local public sentiment for the correction of the elements of danger existing in their water supply systems.

In addition to this work by the laboratory, special investigations have been conducted by the Division of Sanitary Engineering of the general sanitary conditions in those cities in which a high typhoid mortality has existed for a number of years. Among the cities thus investigated have been Ogdensburg, Niagara Falls, Elmira, Cohoes, Poughkeepsie, Newberg, Mt. Vernon, Dunkirk, and Corning.

Upon the completion of these reports the Commissioner of Health has followed the general plan of requesting a conference with the mayor and other officials and citizens of each city. At such meetings the situation, as found upon investigation, has been presented by the commissioner and his staff and thoroughly explained and discussed. In all instances where these investigations have shown that conditions dangerous to public health existed, improvements have been made or will soon be in effect. The pursuance of such a policy of conferring with the responsible local officials and prominent citizens on matters of public hygiene of local import has rarely failed to give excellent results.

In addition to these methods of direct attack against dangerous conditions in some municipal public water supplies, the director and the chemist of the hygienic laboratory or the other members of the Health Department's staff have investigated in the last two years twenty-five outbreaks of typhoid fever in cities and villages. Of these fifteen were found to have been due to the continuous or

accidental contamination of public water supplies, either by domestic sewage or directly by typhoid infected discharges. Upon the publication of the results of these investigations, but after the municipality has paid a great price for its gross negligence, the usual tardy process of correcting insanitary conditions has usually been inaugurated and some very great improvements in the public water supplies have been brought about. It is a disgrace to have to acknowledge the necessity for the operation at present of this most wasteful and extravagant method of educating the public to the essential requirements of a correct municipal hygiene.

Dr. Eugene H. Porter, the present State Commissioner of Health, saw early in his term of service that an educational program for the instruction of local health officers and physicians, regarding the essential principles of the protection, purification, and general control of public water supplies, was likely to be productive of good results. He, therefore, inaugurated a system of meetings, or sanitary institutes. These meetings have been held in various parts of the state, usually during the winter. The programs have consisted to a large extent of papers by the members of the department's staff on the various aspects of the character of the different types of water sources, the methods and nature of their pollution, the means of natural and artificial purification, and their inspection and protection. What might be called a hygienic exhibition, consisting, among other articles, of models of some of the types of water filtration systems and of sewage disposal plants, has been effectively utilized in these institutes. The attendance of health officers, physicians, and citizens has been excellent, and good results have been obtained. In addition to these institutes, the programs of the annual conferences of health officers have always contained one or more papers on these various aspects of water supply problems.

Three laboratory courses for health officers have been given at the State Hygienic Laboratory. In addition to instruction in other subjects, demonstrations of methods of analysis and examinations of water have been given, and conferences upon minor water supply problems have been held with the laboratory staff by those attending.

In addition to the activities just enumerated, and perhaps of greater importance in the protection of the public water supplies, is the enforcement of the act of 1903, which sought to prevent or regulate the pollution of the public waters in New York state. In brief, the law provided that after the date of its passage no sewage or other waste matter should be allowed to discharge into any of the waters of the state without the permission of the State Commissioner of Health. Important provisions, however, were inserted, allowing all discharges of such materials which were then taking place to continue unless those responsible for them desired to change or enlarge their sewerage system, in which case they became subject to the judgment of the Commissioner of Health in accordance with the strict provisions of the law.

The law was given special strength by requiring the immediate registration of all existing sewerage systems, and providing that no changes or alterations could be made until plans for the same should have been submitted to the State Commissioner of Health and approved by him. Suitable penalties and opportunities for obtaining restraining injunctions were provided for in the act.

Under this law marked progress has been made in the prevention of the pollution of New York waters. But few municipalities are so lacking in progress that changes in their sewerage systems do not become necessary, and in this way the State Commissioner of Health is gradually having the opportunity to pass upon the pollution of streams by public sewers. To acquire complete supervision over the long-existing private sewers and industrial waste discharge systems will require a longer period, as enlargements and changes in them are less frequent.

However, even if the Commissioner of Health had been given immediate authority to order the cessation of the pollution of public waters, a considerable time would have been necessary to bring about the elimination of all pollution of public waters in a state the size and age of New York. Work of this character requires the careful preparation of a definite program, based upon accurate knowledge of not only existing conditions, but of the past as well, together with a clear insight into future requirements.

It has been unfortunate, as I have already remarked, that most

of the data and facts upon which such a program could be founded did not exist in compiled form at the time the law was enacted. Thus the duty devolved upon the State Department of Health not only to undertake the work of enforcing the law, but also to make a sanitary survey of the state so as to obtain a full knowledge of existing conditions. With inadequate appropriations, the present Commissioner of Health undertook this task and has accomplished excellent results through the activity and support of his corps of sanitary engineers, at the head of which is Mr. Theodore Horton, a native of Massachusetts and a member of this Association.

Time will not permit me to discuss all the aspects of these accomplishments. One of the more important has been the sanitary survey of the important watersheds of the state, including the preparations of maps of the same, showing the chief types and sources of pollution. With the compilation of this data evidence became available for rendering sound decisions as to the degree of sewage purification which should be required of municipalities when the latter submit plans for sewers and sewage disposal for the department's approval according to law.

The grossly polluted public waters in New York state are not utilized to any great extent for potable supplies. In the cases where they are so utilized, filtration systems have been installed for their purification. The most important protection needed for the majority of the potable water supplies is the prevention of the occasional or accidental pollution of a source, ordinarily in good sanitary condition, and the proper control and supervision of the numerous filtration systems.

For the former, the protection afforded by the State Department's rules as already described might well be reinforced by additional provisions of law and by greatly increased appropriations for the additional engineers and inspectors needed to make certain that the violations of the rules are immediately brought to the attention of those responsible for their correction.

The law should be amended in such a manner as to increase the value of the department's rules to the various local boards of water commissioners or water companies without working injustice to the owners of riparian rights upon the watersheds. Above all,

however, the amendments shou'd provide that all plans for new water supplies or for the alteration or enlargement of existing ones, should be submitted to the State Department of Health for approval before their installation could be legally accomplished.

Not only are increased appropriations needed for the work of the engineers, but also for the laboratory study of the existing conditions from the chemical and biological standpoints.

We are painfully aware that except for the scientific investigations carried out for the New York City commissions on additional water supplies and those made by investigators in the employ of some of the larger cities, such as Buffalo, Rochester, and Albany, there has been but little available data of a scientific and technical character systematically arranged which relates to the sanitary quality of the large bodies of surface waters in New York State, and practically nothing regarding the condition of the ground waters except upon Long Island. These latter are, of course, not so important as the former, as they are less subject to pollution.

A systematic study from the laboratory standpoint of all the natural water resources of the state is most desirable; but it cannot be undertaken until very much larger appropriations are made for the state hygienic laboratory.

Only a *slightly increased* appropriation for the laboratory would make it possible to analyze the water from all supplies more frequently; to encourage more efficient water filtration by determining at short intervals the quality of the work done by the filter plants; and to improve the character of the effluents from sewage disposal plants by the assistance it would be to those in charge of such plants to have frequent analyses made of the effluents and of the sewage in successive stages of the processes.

Personally I am of the opinion that not until provision has been made for our efforts in these directions should resources be directed toward the solution of fundamental problems in water and sewage purification and the elimination of trade wastes, by original research. For its successful prosecution, scientific research requires a well-developed foundation of routine accomplishment. By the intelligent and progressive development of the latter field

we bring about conditions favoring the successful excursions into the fields of the unknown.

We in New York would like well to follow the example of Massachusetts and enter the domain of original research but we realize the necessity for the better preparation of our field of effort and for a more accurate knowledge of the problems involved before we make the venture.

DISCUSSION.

THE PRESIDENT. Dr. Pease's paper is now before you.

ROBERT S. WESTON.* I became acquainted with Dr. Pease about ten years ago at a meeting of the American Public Health Association. I have met him at least once a year since, and I want you all to know how large a part of the excellent beginning which the state of New York has made is due to Dr. Pease's personal efforts. I know that he has worked day and night to make this thing a possibility in his own state, and he has done it with very great devotion and at great personal sacrifice.

I think it is very evident from what he has said that the educational part of the preventive work which has to be done against typhoid fever is a very important one. We have reached a place in Massachusetts where further work in the improvement of our water-works systems and sewage disposal plants will have but little effect on the lowering of the typhoid fever death-rate, and where a portion of the money which is now spent for laboratory work and sanitary engineering work might be in the future diverted profitably toward the employment of what might be called typhoid fever missionaries to instruct the local authorities and local physicians in the prevention of typhoid fever by the prevention of throwing away the dejecta of the patients, thus estopping contamination at its source. We have done the more obvious and general work and have reason to feel proud of our State Board of Health for doing it so well. Next must come the more local and more difficult task of the sanitary education of small localities.

PROF. WILLIAM T. SEDGWICK.† Mr. President, as I sat here I have been thinking of one great oversight that seems to me to

* Sanitary Expert, Boston, Mass.

† Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.

have occurred when Grover Cleveland died. We heard much then of the various things that he had done, but so far as I know nobody pointed out the fact that he either invented or introduced into common use the phrase "a campaign of education," a phrase which has become the watchword of our modern life, and nowhere more, perhaps, than in this matter of sanitation, so much so that I was glad to hear Dr. Pease say in the earlier part of his paper that it was necessary in all these things to have "a campaign of education."

We were fortunate in Massachusetts when our State Board of Health was reorganized in 1886 that the reorganization was in the hands of a man like our honorary member, Dr. Walcott, who was broad enough to be a good deal more than a physician, and who realized that we had to bring engineering and law to the service of the State Board of Health, ours being a board and not a single-headed commission; and that that board approached these problems *de novo*, and saw that we needed to consider how to go to work to get hold of our water supplies by the right end, and to get at them quickly. If you will turn back to that original act of 1886, which called for the submission to the board of all plans involving changes or improvements in our water supply and sewerage systems, you will realize, I think, as never before, that we were fortunate in having that provision inserted in the statute so that all these matters come under the State Board of Health, i. e., our central state sanitary authority similar to that of the commissioner in New York. That was more than a happy accident; it was a real stroke of genius on the part of the men who, without any particular models except those of Old England, planned for this portion of New England what we think to be the best form of procedure.

We have been greatly favored to-day in hearing about this good work which has been done in the state of New York. It is necessary work and it paves the way for still better work. The hygienic laboratory ought to be strengthened there, the hands of the commissioner ought to be upheld. But I think there is one thing that the state of New York wants quite as much as it does these other matters. It wants a kind of New England Water Works Association which shall bring together the practical managers of

water works, the men behind the guns, from all over the state of New York into a meeting like this, and shall bring Dr. Porter, Dr. Pease, Mr. Horton, and all the others connected with the work into close touch with the practical men. I have known this Association for a good while. Its membership is not limited to Massachusetts; it is not limited even to New England; but I really believe that one of the strongest forces that we have had in New England for the improvement of our water supplies has been this voluntary association of professional craftsmen, water supply men, for the study of these great and important public problems. This association began very early inviting to its membership other prominent water supply men, such as chemists, bacteriologists, and the like. Professor Drown and others now gone used to attend even the early meetings and were always welcome. And that happy conjunction of experts with practical men has gone very far, not only toward the actual improvement of supplies, but toward sound legislative work and toward higher standards, toward that campaign of education which has enabled us in New England to get on as far as we have got.

It is our proud boast that now all over New England the water supplies, broadly speaking, are in good condition. There are exceptions, of course, but, broadly speaking, they are indeed so. And that they are in good condition is very largely due to the cooperation of practical men with scientific men. And as a timely illustration we are hearing from Dr. Pease to-day; we are learning of things that are up to date in a sister state which is a veritable empire in itself. I think we may well congratulate the state of New York that it has got this health administration and that it is carrying on work in this practical direction.

I believe that Dr. Pease is quite right. They must begin at the nearest and most urgent point; they must get things into as good shape as they can immediately before going into elaborate researches; and I do not believe there would be any better way of making the wheels turn rapidly than to form an association like this one, and, until then, to get this one, from time to time, to meet in New York state.

ELBERT E. LOCHRIDGE.* Mr. President, we have had this word

* Chief Engineer Springfield Water Department, Springfield, Mass.

from New York as to what they are trying to do and what they are doing there, and the statement of the conditions on their watersheds. I would like to bring before the New England members of this Association a point that we have to meet right here at home this fall. We have gotten our watersheds in pretty good shape; we have looked out for their cleanliness; we have gotten adequate storage; we have gotten water supplies which, on account of this storage, in a way take care of themselves with the ordinary care which they can be given. But this fall our water supplies are all drawn low. In Springfield we have but about two months' supply left, and we are beginning to get a little frightened. In several other towns in the western part of the state the reservoirs are very low, and I have no doubt the same thing is true all over New England; I know it is through Connecticut.

With this low stage of the impounded water and the frost which is just about to go into the ground, we are going to have water coming down from melting snows and from heavy rains and filling our reservoirs and giving us for use immediately unstored water; and it seems to me time to call attention very decidedly to the sanitary conditions of our watersheds, as there has been no time in years when the water will go so directly from the watershed, giving the land the wash it needs, and that we do not need for a water supply, as drinking water.

Professor Sedgwick. May I add a word which is suggested by what Mr. Lochridge has said. A young man in my employ in another state called my attention the other day to the fact that the present low state of our water supplies with the general absence of typhoid fever made the old Pettenkofer theory look, as he expressed it, "like thirty cents." That theory was that when we have low ground water, we have high typhoid. Now, we haven't been having high typhoid this autumn of very low ground water, at least in most places we haven't been, and I believe the reason to be just what Mr. Lochridge suggests, namely, that the germs are held back. They have not been allowed to get into the water, or have been unable to get into the water. And he utters a most timely warning when he reminds us that the great epidemics of Plymouth, Penn., and of New Haven, Conn., both occurred under precisely these conditions of heavy rains and melting snows after a

long period of drought, with the washing in of stuff accumulated previously and held back upon the banks.

PROF. LEONARD P. KINNICUTT.* I should like to say a few words suggested by what Mr. Lochridge has said. First, however, I wish to express my appreciation of Dr. Pease's account of what the board which he represents has accomplished in the state of New York. I was especially interested in what he said regarding the educational movement, and I believe the holding of sanitary institute meetings all over the state will do more for good sanitation in New York than any other one thing. Such a movement would do a great deal of good in our state where a large majority of the people know nothing and consequently care very little about municipal sanitation. In my own city, for instance, the money necessary to purify satisfactorily the sewage of the city is very, very slow in being appropriated by the city government, because the citizens have absolutely no idea of the necessity of preventing the pollution of inland waters. Once arouse them to this necessity and the common council would quickly find the means for the carrying out of their desires. What better way of arousing interest in municipal sanitation is there than by an educational movement such as Dr. Pease has described?

Regarding the work of the New York State Department of Health, I have seen the results in two or three of the manufacturing towns of northern New York. Ballston Spa, for instance, where all its sewage two years ago ran untreated into Saratoga Lake, now on request or demand of the department has built septic tanks and contact beds for the treatment of sewage.

Take the manufacturing town of Gloversville, with a sewage remarkable for the amount of trade waste it contains; they have been compelled to take action and are now conducting, under the supervision of Harrison B. Eddy, one of our members, a most interesting series of experiments so as to be able to treat the sewage in a satisfactory manner. The same can be said for towns and cities all through the state, and is the visible result of the work that Dr. Pease has so well described to us to-day.

This is a long introduction to what I really rose to speak about, and which was suggested to me when Mr. Lochridge said that as a

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

rule the water supplies of Massachusetts are in a state that they can take care of themselves. To that statement I cannot agree. Our water supplies are not in a state where they can take care of themselves. They need and require constant attention and supervision. Take, for instance, the water supply of Worcester, which, like many Massachusetts towns, is an impounded reservoir supply, and may be considered as an excellent supply. The watershed contains no small villages and is sparsely inhabited, yet it is not a water supply that can take care of itself, nor a supply without sources of danger, sources that may at any time give rise to a typhoid fever epidemic. What are these sources? On the watershed of one of the impounded reservoirs there are ten sources where it is possible for animal matter, namely, the refuse from man or man's habitations, to pollute the water. On the watershed of the other reservoir the sources of pollution are not so many, but the reservoir is situated within two miles from the end of one of the most popular trolley lines, and on Sundays and holidays many persons can be seen wandering along the shores of the reservoir. What is true of Worcester is true of many impounded reservoirs in our state, and such water supplies cannot take care of themselves, but need constant supervision and inspection. Every watershed of a potable water should have special guards, appointed by the water board or board of health, whose sole duty should be the guarding of the watershed from pollution.

Professor Sedgwick and Mr. Lochridge have pointed out the danger of pollution of impounded waters at the present time due to the fact that the water in all our reservoirs is low, and that the first real storm will not only bring into the reservoir all the dirt that has accumulated during the past dry summer and autumn, but, owing to the small amount of water in the reservoirs, there will be little time for sedimentation, and the water from the watershed will quickly be carried into the supply pipes. The warning that they have given of the necessity of immediately inspecting the watersheds and removing all sources of pollution is most timely, and if not heeded will be sure to result in a high typhoid fever death-rate during the present winter or coming spring.

The effect of a slight rainfall such as we had in Worcester two weeks ago was shown by the immediate increase of about fifty

per cent. in the number of bacteria in a given quantity of one of our reservoir waters.

DR. PEASE. Mr. President and Members of the Association: I wish to thank you for the very kind expressions which have been voiced this afternoon, and I am particularly gratified at the manner in which you have taken the matter of the educational work which we are trying to carry on in New York state. Just as an example of the fact that people really are interested in these hygienic problems, I would like to relate an instance where we showed this hygienic exhibition which I spoke of — models of sand filtration systems and mechanical filtration systems and of septic tanks. We demonstrated this in conjunction with our large traveling tuberculosis exhibition in the city of Albany, and we had to get our demonstrators to keep the people away from the hygienic exhibitions in order to interest them in the tuberculosis exhibit.

Our people are tremendously interested in all these lines of technical work conducted by boards of health and particularly by water departments, and the only reason they do not take even more interest and know more about them is because the water departments do not organize little excursions out to the filtration systems to demonstrate to the people what they are actually doing. The Health Department of the state of New York would have gone on with meager appropriations until the crack of doom if they had not interested the people of the state in what they were doing. The old method had been tried for nearly an entire generation, and it was almost impossible to get additional money out of the legislature. Now we are going to get it because the people are interested in our work and will see to it that proper appropriations are made.

R. C. P. COGGESHALL.* Mr. President, as I am personally largely responsible for the invitation which brought Dr. Pease here, I want to say that I feel more than repaid by what has been said by him and by the discussion that has taken place, and I sincerely hope that we will have the pleasure of hearing him again.

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* Superintendent Water Works, New Bedford, Mass.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 9, 1908.

President Martin in the chair (Vice-President King presiding later).

The following members and guests were in attendance:

Honorary Member.

F. W. Shepperd. — 1.

Members.

C. H. Baldwin, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, J. E. Beals, F. D. Berry, A. E. Blackmer, J. W. Blackmer, George Bowers, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, C. E. Chandler, J. C. Chase, Harry W. Clark, R. C. P. Coggeshall, M. F. Collins, G. W. Cutting, Jr., F. W. Dean, John Doyle, M. J. Doyle, E. D. Eldridge, J. A. Fitch, F. F. Forbes, E. V. French, F. L. Fuller, C. W. Gilbert, D. H. Gilderson, Albert S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., D. A. Heffernan, J. L. Howard, C. L. Howes, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, J. J. Kirkpatrick, Hugh McLean, N. A. McMillen, D. E. Makepeace, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, F. L. Northrop, E. M. Peck, T. A. Peirce, A. M. Quick, Henry Roberts, L. C. Robinson, Ransom Rowe, H. W. Sanderson, A. L. Sawyer, W. H. Sears, E. M. Shedd, C. W. Sherman, W. E. Smith, G. A. Stacy, J. T. Stevens, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, G. W. Travis, L. L. Tribus, W. H. Vaughn, C. K. Walker, J. H. Walsh, R. S. Weston, F. B. Wilkins, F. I. Winslow, G. E. Winslow. — 84.

Associates.

The Anderson Coupling Company, by Charles E. Pratt; Ashton Valve Company, by C. W. Houghton; Builders' Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edward F. Hughes; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Sons Company, by Charles F. Glavin; H. Mueller Manufacturing Company,

by George A. Caldwell; National Meter Company, by C. H. Baldwin, H. L. Weston, and J. G. Lufkin; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Union Water Meter Company, by Edward P. King; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. H. VanWinkle. — 21.

GUESTS.

R. Lorine, M.D., Coronado Beach, Cal.; J. G. Hill, water commissioner, Lowell, Mass.; John H. Damon, Plymouth, Mass.; A. Fleming, water commissioner, Lawrence, Mass.; and E. L. Field, Northfield, Vt. — 5.

On motion of Mr. Bancroft the Secretary was directed to cast the ballot of the Association in favor of the election of the following named as active members, and he having done so, they were declared duly elected: O. C. Merrill, Berkeley, Cal., assistant engineer reporting on the practicability and cost of a private water supply for the buildings and campus of the University of California at Berkeley; Dr. John C. Otis, Poughkeepsie, N. Y., commissioner of public works and president of the Board of Public Works.

The first paper on the program for the afternoon was by Mr. Leonard Metcalf, consulting engineer, Boston, Mass., on "Wrought-Iron Cement-Lined Water Pipe." Before presenting his paper Mr. Metcalf said:

"I would like to take this opportunity of saying a word to you in regard to the work of your Committee on Water and Water Power Diversion Awards. You will recollect that we sent out postal-card inquiries to the membership some time ago asking for replies from all who had information in regard to damages which had been awarded, or awards which had been made under order of the court or other judicial authority in water-power diversion cases, and we have received a certain number of replies. It seemed to us, however, that we ought to have more than we have thus far received, and we are, therefore, sending out a second set of postal cards, asking you if you will not please return them, stating definitely whether you have or have not any information which you can give us on this point. We don't want to let any good information escape the Association if we can help it. We are also sending out to those who have signified the fact that they

have such information circulars upon which the essential data for which we are asking can be given, and we will be very glad to send them to any others whom you may suggest to us as probably having information, if we haven't them upon our list."

Mr. Metcalf then proceeded to give a synopsis of his paper, which was before the members in proof print. The following-named gentlemen took part in the discussion: Arthur E. Blackmer, Robert S. Weston, E. W. Kent, R. C. P. Coggeshall, Frank L. Fuller, Frank A. Barbour, Leonard C. Robinson, President Martin, John C. Chase, Joseph A. Fitch, J. C. Hammond, Jr., Edward V. French, and Edwin C. Brooks.

The next paper was entitled "Newton (N. J.) Water Works, with Special Relationship to the Storage and Diversion Features and Legal Proceedings Growing Therefrom," by Louis L. Tribus, consulting engineer, New York. The subject was discussed by Richard A. Hale, Charles E. Chandler, William S. Johnson, George A. King, and Leonard Metcalf.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 13, 1909.

The President, Mr. Alfred E. Martin, in the chair.

The following-named members and guests were present:

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, G. A. P. Bucknam, James Burnie, W. L. Butcher, L. G. Carleton, George Cassell, J. H. Child, C. E. Childs, F. L. Clapp, H. W. Clark, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, G. W. Cutting, Jr., L. E. Daboll, C. E. Davis, M. J. Doyle, E. R. Dyer, E. D. Eldridge, C. R. Felton, F. F. Forbes, F. L. Fuller, F. J. Gifford, C. W. Gilbert, J. C. Gilbert, Albert S. Glover, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, D. A. Heffernan, H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, J. J. Kirkpatrick, H. O. Lacount, E. E. Lochridge, A R. McCallum, Hugh McLean, N. A. McMillen,

D. E. Makepeace, A. E. Martin, F. E. Merrill, G. F. Merrill, H. A. Miller, William Naylor, F. L. Northrop, E. M. Peck, Henry Roberts, H. E. Royce, P. R. Sanders, E. M. Shedd, C. W. Sherman, G. A. Stacy, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. K. Walker, J. C. Whitney, George E. Winslow. — 78.

ASSOCIATES.

Allen & Reed, Inc., by Murray G. Millikin; Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by F. M. Bates; Builders' Iron Foundry Company, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edw. F. Hughes; George E. Gilchrist Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, H. D. Winton, and Walter A. Hersey; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Sons Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by H. G. Lufkin and H. L. Weston; New York Continental Jewell Filtration Company, by R. E. Milligan; Norwood Engineering Company, by H. W. Hosford; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Neptune Meter Company, by H. H. Kinsey; Union Water Meter Company, by Edw. P. King. — 21.

GUESTS.

Millard F. Hicks, treasurer Portland Water District, and Chesley L. Ward, superintendent Meter Department, Portland, Me.; Dwight L. Agnew, North Scituate, Mass.; Ivers M. Low, superintendent, Weymouth, Mass.; F. H. Hayes, of the F. H. Hayes Machinery Company, Boston, Mass.; F. J. Merrill, W. Hoare, and E. C. Allen, engineer, Manchester, Mass.; George Goodhue, Concord, N. H.; C. E. Hall, Wallingford, Conn.; C. H. Tuttle, Bristol, R. I. — 11.

Mr. Bertram Brewer, city engineer of Waltham, Mass., gave an interesting talk, illustrated by lantern slides, on "Cuba and the Havana Water Works."

The following-named were elected to membership, their applications having been duly approved, and one ballot cast for them by the Secretary, in accordance with the vote of the Association on motion of Mr. Frank L. Fuller:

Active. — Herbert D. Pease, Albany, N. Y., director of the New York Hygienic Laboratory; Leonard M. Wachter, Albany, N. Y., chemist at Albany Filtration Plant and sanitary chemist, New York State Department of Health; Arthur E. O'Neil, Watertown,

Mass., superintendent of pumping stations, Metropolitan Water Works; Millard F. Hicks, Portland, Me., treasurer Portland Water District; Charles H. Tuttle, Bristol, R. I., superintendent Bristol and Warren Water Works; Fred M. Hutchinson, Somerville, Mass., engineer and foreman with Somerville Water Works.

Associate. — N. H. Hayes, Hayes Machinery Company, South Boston, Mass.

Mr. Alfred E. Martin, the retiring President, then delivered the following address:

Address of the Retiring President.

Gentlemen of the New England Water Works Association, — Among the many memories which have kept pace with my journeyings from boyhood days is one of a remark attributed to a certain boy in answer to another's attempt to air his self-supposed superior knowledge of a certain dead language by quoting the old, familiar phrase, "*Tempus fugit.*" "Oh, yes," said the former, "I know that, and my father says it *fugits* like everything." It seems to me as I stand here to-day that the above applies very forcibly to the year just closed, for no twelve months of my existence have ever gone into history with such remarkable celerity. I can hardly realize that it is fully a year since my advent as your president, and I almost feel like singing with the poet,

"Backward, turn backward, O Time, in thy flight."

But time never turns backward, and be our journey long or short, few of us, I think, would care to try it over or make a wiser use of our opportunities.

But Father Time has a sadder story for us to-day, for the "grim reaper" has been busy in our ranks and has taken eight of our active and one of our honorary members on the journey to that country from whose bourn no traveler returns. I will merely call their names here, for their history has already been inscribed on our records, and to those of you who knew them intimately there is no necessity for eulogy such as my ungifted tongue could pronounce. I will ask the members to stand while I read the list of those who have crossed the great divide during the last year:

R. C. Bacot, Jr., superintendent meter department, Port Chester, N. Y. Elected to membership in this association December 12, 1888. Died December 12, 1908.

Charles H. Campbell, 126 Liberty Street, New York City. Elected to membership June 28, 1905. Died March 24, 1908.

Bartholomew Dwyer, assistant superintendent water works, Hartford, Conn. Elected to membership September 13, 1905. Died December 14, 1907.

I. T. Farnham, city engineer, Newton, Mass. Elected to membership December 13, 1905. Died September 19, 1908.

A. W. Hunking, Lowell, Mass. Elected to membership June 11, 1890. Died November 12, 1908.

J. O. A. Laforest, Quebec, Canada. Elected to membership December 14, 1892. Died December 28, 1907.

Claude P. Nibecker, sanitary engineer, Pittsburg, Pa. Elected to membership November 19, 1905. Died November 10, 1908.

George E. Wilde, assistant superintendent Distribution Department, Metropolitan Water Works, Boston, Mass. Elected to membership June 18, 1886. Died July 17, 1908.

Charles Hermany, chief engineer and superintendent of the Louisville, Ky., Water Company. Elected honorary member of this Association September 14, 1904. Died January 18, 1908.

All of the above, except the last named, were active members of this Association, and he was an honorary member.

Our total membership is now 696, a net loss for the year of 6. At first thought this would appear a retrogression, but when we note that the above is the absolute *net membership*, that all whose assessments were overdue have been dropped from the rolls, it is not in reality so bad as it seems, for we have 696 actual paying members,—no dead wood at all.

Right here it may not be out of place to suggest that if some way could be devised to keep the Secretary more closely in touch with those members who are liable to get in arrears, it might be possible to avoid such a large list of delinquents as has appeared this year, namely, thirty-eight, of whom seventeen have been reinstated upon payment of all arrearages. It would seem a good plan for the Executive Committee to take this matter up and recommend an amendment to the By-Laws to the effect that the

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	702	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10

* Deceased.

† Not including December JOURNAL and reprints.

‡ Does not include $1 815 invested in bonds.

Secretary shall remind those who are getting behind in their dues at least quarterly, and it seems to me that by thus oftener calling their attention to the fact, fewer would let their membership lapse by neglect or forgetfulness. I can hardly believe that twenty-one members would have allowed themselves to be dropped from this Association if they could have been reminded of their liability earlier in the game, so to speak.

Our finances are still in a prosperous condition, the Treasurer's report showing upward of $2 700 cash on hand, besides an investment of $1 815 for railroad bonds, the par value of which is $2 000, and which would now sell in the market for $1 920, thus making available assets of over $4 600, an increase of $600 or more over last year.

Our JOURNAL has kept pace with the growth of this Association, and is, as it has always been, an up-to-date publication. It was with much regret that I learned as long ago as our June meeting that Mr. Sherman would not be a candidate for reëlection as its editor. For ten years he has had charge of its publication, and under his care it has grown to be of the greatest value to the members of the Association. He has given to it fully and unreservedly of his time and strength, and it is not surprising that with the increased responsibilities of his regular occupation he has come to feel that it is too much of a burden to be longer borne. Without doubt much of its value and worth to-day are due to his ceaseless and untiring devotion to and love for the Association, whose proceedings it chronicles. If we must lose him we are to be congratulated that in his successor we are to have one who will undoubtedly follow in his footsteps and be guided and advised, for a time at least, by his experienced mind and wise counsels. His table showing the progress of the Association from its beginning is again published as a part of this report, and includes the year 1908.

Our winter meetings have proven helpful and interesting and have all been well attended, and I think that none who have been present at them have ever gone away with the feeling that they have not been well repaid for the effort, if in no other way than in the sociability and good-fellowship thus engendered between the members.

On the 21st of June the Association visited Plymouth, and under the efficient management of Messrs. King, of Taunton, and Tower, of Cohasset, the committee appointed to arrange for the excursion, also in spite of the weather, which was extremely hot and unfavorable, about eighty members and guests passed a very enjoyable day. After a short meeting at the armory, where we were welcomed and very hospitably entertained by the town officials, the workshop of the water department was inspected and the process of manufacturing large-size wrought-iron, cement-lined water pipe was witnessed and proved interesting to us all. Pilgrim Hall, the Rock, and the monument were the next objects of interest, and then electric cars were boarded for a ride to Hotel Pilgrim, where an excellent shore dinner was served. An interesting incident of the day was the meeting of the surviving charter members of this Association, six in number, namely, H. G. Holden, R. W. Bagnell, C. K. Walker, F. E. Hall, A. S. Glover, and R. C. P. Coggeshall, and as a result of the meeting a group photograph of them now adorns a page of the September number of the JOURNAL. Of the six, four are ex-presidents of the Association, the fifth has been our secretary and junior editor of the JOURNAL, and the sixth, Mr. Bagnell, has been made a life member of this Association. After the dinner an opportunity was given to witness the work of laying the before-mentioned cement-lined pipe. The speaker was forced to miss this part of the program by a long search for head covering, caused by a too careful waiter who could not remember the place where he put it. I have no doubt the process was interesting and instructive to those who saw it.

The annual convention of the Association, in accordance with the expressed wish of many of its members, was held in Atlantic City, N. J., September 23, 24, and 25. The attendance was not so large as could have been desired or expected, but those who were present were well repaid. The headquarters of the Association were at the Traymore Hotel. Upwards of two hundred and fifty members and guests were registered, nearly all of whom made the Traymore their home for the three days. The business meetings were well attended and very helpful, and many able papers, followed by general discussion, were presented. I wish to express my personal obligation to the general chairman, Allen Hazen, for

his zeal in marshaling members to the convention hall where the business sessions were held.

While business was the chief object of the assemblage, yet there was time for recreation as well. The roller chair parade on the board walk, in which over ninety double chairs were in line, was a novel and pleasing experience. The reception to the officers and their wives which followed was enjoyable and promoted sociability. The exhibition drill of the life-saving crew, which was ordered by the mayor of the city as a compliment to the Association, proved an interesting and instructive feature. On Friday, the last day, a trolley trip was indulged in to the pumping station of the Atlantic City Water Works. Some time was profitably spent looking over the plant, and here the speaker (at least) had his first introduction to that active resident of the state of which so much has been written and spoken, namely, the "Jersey mosquito."

Among the various committees which have been appointed during the year are the following:

At the March meeting a committee of five was appointed to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country.

At the September convention a committee of seven was appointed to gather statistics relative to the depth at which water pipes are laid and the resultant experiences with frozen pipes in New England and different places of the country.

When these committees shall have formulated and presented their final reports they should make a most valuable addition to our literature.

Reports of the Secretary, Treasurer, Editor, and Auditing Committee will show in detail the standing of the Association, financially and otherwise. The faithful work of these officers should not pass unnoticed, and the Association will do well to continue them in office.

My duties of the past year have been lightened by the active and earnest work on the part of the various committees, to whom I return heartfelt thanks.

From the inception of this organization, all through the inter-

vening years to the present time, the work has been characterized by devotedness of purpose which must result in new life ever being diffused throughout the ranks, and in the maintenance of that high standing in the community to which the Association is entitled.

The Secretary, Mr. Willard Kent, submitted the following report:

Report of Secretary.

Mr. President and Members of the New England Water Works Association, — Your Secretary submits the following report of membership, moneys received, and disbursements approved on account of the New England Water Works Association for the year ending December 31, 1908:

MEMBERSHIP.

The present membership of the Association is 696; that of one year ago was 702, a loss of 6 during the year.

The detailed statement of the changes in membership during the past year in the several grades is as follows:

MEMBERS.

January 1, 1908.	Total number		636	
	Withdrawals:			
	Resigned	15		
	Died	8		
	Dropped	38	61	575
	Initiations:			
	January	4		
	February	4		
	March	5		
	June	10		
	September	8		
	November	1		
	December	2		
			34	
	Members elected in 1907, qualified in 1908		2	
				36

	Reinstated:			
	Members dropped in 1907		5	
	Members dropped in 1908		17	22

HONORARY MEMBERS.

January 1, 1908.	Honorary members	15	
	Died	1	14

ASSOCIATES.

January 1, 1908.	Total number of associates			51	
	Withdrawals:				
	Dropped	1			
	Resigned	3	4	47	
	Initiations:				
	February	1			
	September	1		2	49
January 1, 1909.	Total membership				696

SUMMARY OF RECEIPTS AND DISBURSEMENTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1908.

RECEIPTS.

Initiation fees			$170.00
Annual dues:			
Members	$1 920.00		
Associates	750.00	$2 670.00	
Fractional dues:			
Members	$12.00		
Associates	5.00	17.00	
Past dues		20.62	2 707.62
Advertisements			2 118.75
Subscriptions			178.50
JOURNALS sold			264.85
Sundries			86.70
Total receipts			$5 526.42

DISBURSEMENTS.

JOURNAL	$2 219.15
June excursion	19.80
Assistant Secretary	600.00
Stationery and printing	612.89
Rent	400.00
Advertising Agent	264.40
Editor	300.00
Secretary	200.00
Stenographer	206.00
Incidental expenses	155.65
Membership list	171.00
Reprints	279.50
Music	75.00
Stereopticon	57.50
Treasurer	50.00
Badges	72.00
Insurance	15.00
Library	6.00
Total disbursements	$5 703.89
Expenditures in excess of receipts	$177.47

At present there is due the Association:

For advertisements	$498.75
For reprints	19.80
For initiation fees and dues	11.00
For JOURNAL	1.00
For Standard Specifications	1.20
	$531.75

I know of no outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.

1908.			
Jan. 6	Balance on hand		$4 480.30
Aug. 1	Dividend, Peoples' Savings, Worcester,		64.64
Nov. 1	Coupons, L. S. & Mich. So. R. R. bonds		80.00
Dec. 9	Dividend, Mechanics Savings Bank, Reading		35.30
Feb. 7	Rec'd of Willard Kent, Sec'y,	$1 387.90	
March 9	" " " " "	664.70	
April 6	" " " " "	493.10	
May 4	" " " " "	574.95	
June 6	" " " " "	251.05	
July 10	" " " " "	273.95	
Sept. 4	" " " " "	516.87	
Nov. 10	" " " " "	277.15	
Dec. 9	" " " " "	599.05	
1909.			
Jan. 5	" " " " "	487.70	5 526.42
			$10 186.66

EXPENDITURES.

Paid bills, as per itemized statement		$7 475.56
BALANCE ON HAND.		
Deposit, Peoples' Savings Bank	$1 664.64	
" Mechanics Savings Bank	1,000.00	
" First National Bank, Reading	17.59	
Deposit, Liberty Trust Co., Boston	28.87	2 711.10
		$10 186.66

ASSETS AND LIABILITIES.

ASSETS.

Cash balance on hand	$2 711.10
Bonds Nos. 2642 and 2644, Lake Shore & Mich. So. R. R., 4%, due May 1, 1931. Book value, $1,815.00. Market value	1 920.00
	$4 631.10

LIABILITIES.

Bill due Advertising Agent	$62.00
Net assets	4 569.10
	$4 631.10

READING, MASS., January 5, 1909.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1908.		
January 21	Blodget, Merritt & Co., Lake Shore & Mich. So. R. R. bond	$1 815.00
	Accrued interest	18.67
February 7	Samuel Usher, December, '07, JOURNAL and reprints,	594.68
	D. Gillies' Sons, printing	18.00
	W. N. Hughes, printing	43.75
	The Brunswick, music, January meeting	15.00
	L. M. Bancroft & Son, bond	15.00
	American Society of Civil Engineers, binding	6.00
	Hub Engraving Company, plates	4.33
	Miss J. M. Ham, salary for January	50.00
8	D. Gillies' Sons, stationery	52.84
	W. N. Hughes, envelopes and printing	70.00
March 2	The Brunswick, music, February meeting	15.00
	Thomas P. Taylor, stereopticon	10.00
	Hub Engraving Company, plates	8.98
	Miss J. M. Ham, salary for February	50.00
9	W. N. Hughes, printing	1.85
	D. Gillies' Sons, printing	4.00
	William E. Whittaker, work on plans	5.00
	Boston Society of Civil Engineers, rent to February 29, 1908	100.00
30	Hub Engraving Company, plates	9.40
	Samuel Usher, advance copies	15.00
	The Brunswick, March meeting, music	15.00
	Bacon & Burpee, report of January, February, and March meetings	59.00
	Miss J. M. Ham, salary for March	50.00
	Thomas P. Taylor, stereopticon	10.00
	Charles W. Sherman, salary to March 31	75.00
	Charles W. Sherman, copyright, postage, etc.	9.50
April 7	Willard Kent, salary as Secretary to March 31	50.00
	Willard Kent, expenses	60.50
15	Robert J. Thomas, advertising agent, to April 30	69.65
20	Hub Engraving Company, plates	31.99
	Samuel Usher, March JOURNAL and reprints	267.58
	Miss J. M. Ham, salary for April	50.00
	Miss J. M. Ham, sundry expenses	34.65
May 4	W. N. Hughes, envelopes and printing	45.00
	Hub Engraving Company, plates	38.22
	Samuel Usher, printing Constitution and List of Members	171.00
	Amount carried forward	$3 959.59

	Amount brought forward	$3 959.59
May 19	Hub Engraving Company, plates	14.05
	William E. Whittaker, tracings	10.00
	John Wiley & Sons, electro plates	1.25
25	Miss J. M. Ham, salary for May	50.00
June 6	Hub Engraving Company, plates	11.08
	Boston Society of Civil Engineers rent to May 31, 1908	100.00
26	H. D. Atwell, cut of Plymouth and tickets	3.55
	Miss J. M. Ham, salary for June	50.00
July 6	D. Gillies' Sons, printing circulars	11.25
	Willard Kent, salary to July 1	50.00
	Willard Kent, expenses	10.00
	Charles W. Sherman, salary to June 30	75.00
	Charles W. Sherman, expenses	4.75
10	Samuel Usher, June JOURNAL	538.16
23	Samuel Usher, Standard Specifications	27.25
	W. N. Hughes, stamped envelopes and printing	24.00
	Robert J. Thomas, advertising agent, to July 8	69.75
28	Lewis M. Bancroft, deficit, Plymouth Excursion Committee	19.80
	Samuel Usher, reprints	53.00
August 28	Suffolk Engraving Company, plate	3.78
	H. W. Spooner, typewriting	3.00
	Miss J. M. Ham, salary for July	50.00
September 2	Hub Engraving Company, plates	1.70
	Miss J. M. Ham, salary for August	50.00
16	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage, express, etc.	6.00
21	Boston Society of Civil Engineers, rent to August 31,	100.00
	Hub Engraving Company, plates	5.24
October 6	W. N. Hughes, postal cards and circulars	10.75
	Samuel Usher, advance copies	7.50
	Whitehead & Hoag Company, badges	72.00
	Miss J. M. Ham, salary for September	50.00
9	Alfred Moore, stereopticon, Atlantic City	17.50
	Traymore Hotel Company, labor, etc.	7.40
	Hub Engraving Company, plates	2.00
	D. Gillies' Sons, printing circulars	14.75
14	W. N. Hughes, letter heads	4.00
	Bacon & Burpee, report of twenty-seventh annual convention	94.25
	Willard Kent, salary to October 1	50.00
	Willard Kent, expenses	21.00
	Amount carried forward	$5 728.35

	Amount brought forward	$5,728 35
October 14	Hub Engraving Company, plates	2.00
26	Miss J. M. Ham, salary for October	50.00
	Miss J. M. Ham, expenses	82.87
November 24	Thomas P. Taylor, stereopticon	10.00
	The Brunswick, music at November meeting	15.00
	D. Gillies' Sons, printing circulars	4.50
	William E. Whittaker, preparing drawing	1.00
	W. N. Hughes, printing circulars	7.00
	Hub Engraving Company, plates	1.00
27	Hub Engraving Company, plates	17.72
	Miss J. M. Ham, salary for November	50.00
	Robert J. Thomas, advertising agent, to November 30	63.00
December 11	Hub Engraving Company, plates	24.64
	Boston Society of Civil Engineers, rent to November 30, 1908	100.00
	Samuel Usher, September JOURNAL and reprints	355.66
18	Hub Engraving Company, plates	10.80
	The Brunswick, music, December meeting	15.00
	Charles W. Sherman, salary to December 31, 1908,	75.00
	Charles W. Sherman, postage and expenses	6.50
	Thomas P. Taylor, stereopticon	10.00
	Willard Kent, salary to December 31	50.00
	Willard Kent, expenses	43.40
21	W. N. Hughes, dues book and circulars	28.00
	Lewis M. Bancroft, treasurer, salary to December 31, 1908	50.00
25	Miss J. M. Ham, salary for December	50.00
	Miss J. M. Ham, expenses, telephone and postage	32.25
28	Samuel Usher, printing advance copies	27.25
	Bacon & Burpee, reporting November and December meetings	52.75
1909.		
January 6	D. Gillies' Sons, printing	28.50
	W. N. Hughes, printing, Committee on Depth of Laying Water Pipes	49.75
	Samuel Usher, December JOURNAL and reprints	433.62
		$7 475.56

The Editor, Mr. Charles W. Sherman, submitted the following report:

REPORT OF THE EDITOR.

BOSTON, January 13, 1909.

To the New England Water Works Association, — I present the following report for the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION for the year 1908.

The accompanying tabulated statements show in detail the amount of material in the JOURNAL; the receipts and expenditures on account of the JOURNAL for the past year (including the cost of the December JOURNAL and reprints, bills for which were received too late to pay in 1908, and which are consequently not included in the Secretary's and Treasurer's statements); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat larger in total pages, and contains the same number of pages of text, as that of the preceding year; and is larger than any preceding annual volume, with one exception.

Illustrations. — The total cost of illustrations for the year, including printing, has been $355.36, or 13.0 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Advance copies of three of the papers presented during the year have also been printed, one of which has not yet appeared in the JOURNAL. The net cost to the Association for reprints and advance copies has been $203.70 (assuming that the December reprints chargeable to members are promptly paid for).

Circulation. — The present circulation of the JOURNAL is:

Members, all grades	696
Subscribers	60
Exchanges	24
Total	780

a decrease of 5 over the preceding year.

Advertisements. — The December issue contained 25½ pages of paid advertising, which, if maintained throughout the year, would mean an annual income from this source of $1 760. A year ago the figures were 28¼ pages and $1 940, showing considerable decrease during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $49.00 have been sold. Five hundred copies have been printed, at a cost of $27.25, representing a net gain of $21.75 for the year. The net gain up to a year ago had been $139.75, so that the total net gain from this source to date is $161.50. There are still about two hundred and eighty copies of specifications on hand, or about $28.00 worth if sold at retail.

The Association has a credit of $1.69 at the Boston Post-office, being the balance of the money deposited for payment of postage upon the JOURNAL at pound rates. I know of no outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1908.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	58	28	86	–	32	4	4	126	2
2	June	164	10	174	–	30	4	18	226	28
3	September	93	27	120	–	28	4	7	159	5
4	December	110	10	120	8	28	4	10	170	12
	Total	425	75	500	8	118	16	39	681	47

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1908.

RECEIPTS.		EXPENDITURES.	
From advertisements	$2 118.75	For printing JOURNAL	$1 490.75
From sale of JOURNALS	264.85	For preparing illustrations,	207.36
From sale of reprints	28.50	For editor's salary	300.00
From sale of cuts	11.70	For editor's incidentals	28.60
Subscriptions	178.75	For advertising agent's commissions	264.40
	$2 602.55	For reporting	206.00
Net cost of JOURNAL	131.06	For reprints and advance copies	236 50
	$2 733.61	Gross cost of JOURNAL	$2 733.61

TABLE No. 3.

Comparison between Volumes XIV to XXII, Inclusive, Journal of the New England Water Works Association.

	Vol. XIV. 1899–1900.	4 Numbers of Vol. XV. 1900–1901.	Vol. XVI. 1902.	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.	Vol. XXII. 1908.
Average edition (copies printed)	1 100	1 200	1 200	1 200	900	900	900	1 085	1 000
Average membership	583	586	571	587	596	625	665	693	699
Circulation at end of year	640*	617*	648*	656*	667	705	767	785	780
Pages of text	345	363	403	430	491	587	495	500	500
Pages of text per 1 000 members	600	618	707	733	824	939	745	722	715
Total pages, all kinds	485	536	584	619	794	784	662	669	681
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254	995	964	976
Gross Cost:									
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88	3.95	4.01
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87	3.82	3.91
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67	5.85	5.70	5.88
Per member per 1 000 pp. text	9.71	10.13	10.60	10.72	10.00	8.91	7.81	7.62	8.02
Net Cost:									
Total	$347.55	$332.90	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15	$131.06
Per page	.72	.62	1.07	1.25	.82	1.37	.58	.72	.19
Per member	.60	.57	1.09	1.31	1.09	1.72	.58	.70	.19
Per member per 1 000 pages,	1.23	1.06	1.87	2.12	1.30	2.20	.88	1.04	.28
Per member per 1 000 pp. text	1.73	1.57	2.71	3.05	2.22	2.93	1.18	1.39	.39

* Exclusive of three hundred sample copies.

Mr. George Cassell, chairman of Finance Committee, submitted the following report:

REPORT OF FINANCE COMMITTEE.

BOSTON, MASS., January 11, 1909.

We have examined the books and accounts of the Secretary and Treasurer of the New England Water Works Association and find them correct, the several amounts collected by the Secretary having been turned over to the Treasurer and his various disbursements being supported by proper receipts duly approved.

The accounts and books are properly kept and the very satisfactory manner in which this department of the Association is conducted is largely due to the exceedingly efficient service of the Assistant Secretary.

We recommend that the books be closed on the first day of January and remain closed until the annual meeting, in order that the Treasurer and Finance Committee have ample time to attend to their duties.

Respectfully submitted,

GEORGE CASSELL,
JOHN C. CHASE,
WILLIAM E. MAYBURY,
Finance Committee.

MR. CASSELL. I might add, Mr. President, that the recommendation, as made by your Finance Committee, is in order to provide so that the bills approved by the Secretary will get into the hands of the Treasurer before the Treasurer closes his books, thereby avoiding the discrepancy in the two accounts as printed in the JOURNAL, which necessitates a footnote of explanation. The Finance Committee think it would be much better and more satisfactory, and remove any doubt upon anybody's part after reading the JOURNAL, if the suggestion we make is adopted.

On motion of Mr. George A. Stacy the reports of the Secretary, Treasurer, and Editor were accepted and ordered placed on file and spread on the records of the Association.

On motion of Mr. Coggeshall, the report of the Finance Committee was accepted and its recommendation adopted.

REPORTS OF COMMITTEES.

STANDARD SPECIFICATIONS FOR FIRE HYDRANTS.

Mr. H. O. Lacount, chairman of the Committee to Prepare a Standard Specification for Fire Hydrants, presented the following report:

Mr. President and Gentlemen of the New England Water Works Association,— The retiring President in his address gave a list of the committees appointed last year, and as he did not mention the Committee on Hydrants, I presume it is to be inferred that it was appointed more than a year ago. As chairman of the committee, I am forced to agree with the father of the lad mentioned in the retiring President's address that "*tempus fugits* like everything." I will not apologize for Father Time, because he cannot help it, and I feel rather embarrassed in attempting to apologize for the committee for not having made a report to you before. I regret that we have not, and that we are not ready yet to bring out a complete set of specifications. We can, however, report some progress.

The committee has had two meetings, at each of which we spent practically an entire afternoon on the work. We have been in communcation with practically all of the manufacturers of hydrants of whom we have knowledge, have had the benefit of their suggestions, and the matter is gradually taking form. We hope that before the administration on which we begin to-day ends we shall have the subject threshed out to a finish. That you may have some idea along what lines the committee is working, I have here what may be called a skeleton of specifications, which I will read.

Skeleton of Specifications.

1. Size.
   - *a.* Size of hydrants must be designated by the valve opening, at least 5-inch for two hose connections, 6-inch for three or four connections.
   - *b.* Area of waterway at smallest part when hydrant is wide open must not be less than that of the valve opening.
2. General Design.
   - *a.* Any changes in diameter of water passage through the barrel shall have easy curves, all outlets to have well-rounded corners of good radius.
   - *b.* Design such that with ordinary usage hydrants will not cause excessive water hammer.
3. Hose Nipples and Valves.
   - *a.* Nipples of bronze, threaded with fine thread and pinned. "Leading" not permitted.
   - *b.* Hose threads to be same as existing in city where hydrant is to be used; otherwise and where practicable, same as N. F. P. A. Standard, 1906.
   - *c.* Hose valves of bronze or of iron with bronze trimmings, — brief specifications.
4. Hydrant Gate and Seat.
   - *a.* Material.
   - *b.* With gate type of valve sufficient clearance to offset corrosion.
5. Drip Valve.
   - *a.* Positively operating and non-corrodible, to completely drain barrel.
   - *b.* Seat to be securely fastened in barrel; all other parts to be removed through hydrant top.
6. Operating Stem.
   - *a.* Material and size.
   - *b.* Stem nut.
   - *c.* Style of thread, Acme standard.

7. Stuffing Box and Gland.
   a. Material.
   b. Material and size of gland bolts.
8. Hydrant Top.
   a. Weatherproof and provision for oiling.
9. Markings.
10. Hose Caps for all outlets.
11. Test.
    Shop test of 250 or 300 pounds, or twice working pressure.
12. Direction of Opening to the left.

The President. If there is nothing to be said on this report, it will be received as a report of progress and the committee continued. The next business is the report of the committee appointed to collect data relating to awards that have been made for damages resulting from the diversion of water. Mr. Charles T. Main, chairman of the committee, has sent the following communication, which the Secretary will read:

WATER AND WATER POWER DIVERSION.

The Secretary. Mr. Main was unable to be present to-day and has sent the following report of progress:

January 12, 1909.

Your committee desires to report progress. Return postal cards have been sent out to about one hundred and twenty-five members of the Association who had not been previously heard from, with the expectation of being able to get information concerning water and water power diversion awards from many of these members, and a few additional cards were sent out later. Of these there have been about seventy-five cards returned, about fifty of which stated that the signer could furnish no information and about twenty-five contained some information or suggestion.

There have also been sent out to such members as it was thought could give detailed information, blanks covering the data which the committee desires to obtain. Up to the present time only two of these blanks have been filled out and returned.

It would be useless for your committee to attempt to make a report until a large number of these blanks has been filled out and returned. After a number has been returned, the committee will tabulate the returns and prepare them in some form for presentation to the Association, together with such deductions as can be made from them.

CHAS. T. MAIN,
Chairman of the Committee.

THE PRESIDENT. It is to be hoped that there will be a general response to the postal cards sent out. The committee is working hard to gather all the information obtainable on this subject, and the help of the members is certainly due to its efforts.

The next matter in order is the report of the committee to gather statistics relating to the depth at which water pipes are laid, and the resulting experience with frozen pipes. Mr. Stacy will read a communication from Mr. Frank A. Barbour, chairman of the committee.

DEPTH OF WATER PIPES.

MR. GEORGE A. STACY. I have been requested to read a communication from Mr. Barbour, who is not able to be present.

BOSTON, MASS., January 13, 1909.

MR. WILLARD KENT, SECRETARY NEW ENGLAND WATER WORKS ASSOCIATION, TREMONT TEMPLE, CITY:

Dear Sir, — I regret that an engagement prevents my making this report of the Committee on the Depth of Water Pipe personally at the meeting of the Association to be held to-day.

Nothing more than a statement of progress to date can be presented at the present time. Over three hundred copies of the circular have been sent out to members of the New England and American Water Works Associations, these circulars being sent to the superintendents of plants and such engineers as from our knowledge of their work appeared likely to be able to respond with information of value. The circulars were sent out the latter part of December and up to the present time about twenty-five replies have been received. From these replies it is obvious that the information to be obtained from the circulars will be largely negative in character and that in order to obtain information in regard to actual cases of freezing, a personal appeal must be made to engineers and superintendents who have had such experience.

Yours truly,

F. A. BARBOUR.

In connection with this matter, Mr. President, which is an important one, as are also those that the other committees have under consideration, let me say that the value of the work of this committee is dependent largely on the response which the members of the Association make to the circulars sent out. The great value of our JOURNAL, it seems to me, is in its record of the experiences

that we have had in water-works construction and management, and our progress, if we do make progress, is largely due to the application of the experience of others to situations in which we may be placed. So I think you owe it to the members of the Association and to this committee to make replies to the inquiries which have been sent out. It is not necessary in order to do this that you should have a technical knowledge of some deep subject or of some intricate mathematical or astronomical instrument. You have all had a little touch of frost somewhere, and that, as I understand it, is what the committee wants to find out about. Put it in the simplest form that you can. If you cannot remember the exact details, give your experience as fully as you can; it will be a help to the committee and it may be of great help to us. And so, in behalf of the committee, while I have not been solicited to do so, but having served on committees myself, I appeal to you, gentlemen, to reply to the circular as fully and as speedily as you can, in order that we may have a report from the committee which will be of value to the JOURNAL and to the Association.

MR. CHARLES W. SHERMAN. Mr. President, if I may add a word to Mr. Stacy's appeal, I want to suggest that members of the Association, whether they have had any experience in this matter themselves or not, can perhaps send to the chairman of the committee the names of water-works men, who may not be members of the Association, but who can contribute information of value along this line. My own personal experience has not been such as to enable me to furnish any information to the committee, although I received a blank, but I happened to know a gentleman, not a member of the Association, who had a considerable amount of information, to whom I forwarded the blank, and I am glad to say that this morning I received it back from him filled out.

THE PRESIDENT. I think the remarks of the last two speakers are very timely and forcible. I trust that the members will follow out their suggestions fully.

The next matter is the report of the committee to compile information in relation to awards that have been made in water-works valuation cases. Mr. Desmond FitzGerald, I believe, is chairman of the committee. As he is not present, is there any one here who has anything to say for the committee?

AWARDS IN WATER-WORKS VALUATION CASES.

MR. JOHN C. CHASE. Mr. President, I happen to be a member of that committee, and I can report to a limited extent. Some few days after the committee was appointed I received a communication from a member suggesting that we elect Mr. Desmond FitzGerald chairman, to which I cheerfully assented. I heard nothing more until about two months ago, when I had a letter from Mr. Allen Hazen stating that Mr. FitzGerald had positively declined to serve, and that he had been substituted as chairman, and asking my assent to a certain report, or suggesting that the matter had been thoroughly covered by a paper or report which had been presented to another body, and that we use that as our report. I assented to it, with some suggestion of modifications, that perhaps we ought to report something which did not refer to a certain paper. Mr. Hazen said that he positively would not serve as chairman, and suggested the appointment of some one else — I cannot recall at this moment just who — and that is all I can tell you about the committee now. I have had no further communication. I think, however, if the committee is granted further time, that in due time something will be heard from it.

(The following report was received too late to be presented at the meeting.)

REPORT OF COMMITTEE TO LOOK AFTER AND KEEP TRACK OF LEGISLATION AND OTHER MATTERS PERTAINING TO THE CONSERVATION, DEVELOPMENT, AND UTILIZATION OF THE NATURAL RESOURCES OF THE COUNTRY.

The chairman begs leave to report as follows:

The movement for the conservation of the natural resources of the country has been so fully reported in the daily, literary, and technical press that only a very brief summary seems desirable here, and that chiefly for purposes of record.

Two great conservation conferences were held at Washington during the past year, on the initiative of the President of the United States. There has also been held a conference of New England governors, and I believe the governors of some of the other portions of the country have got together on this subject. Some of the engineering societies have given careful consideration to conservation matters. At a meeting of this Association held at Atlantic City last September, papers on some of the conservation features of water and forests were presented, through the agency of your committee.

Besides the large national commission on natural resources, several of the states of the Union have appointed conservation commissions, in accordance with recommendations adopted at the White House Conference of governors last May.

What can this Association do to further so worthy a cause? Just at present the chairman would suggest nothing specific for the Association as such to do except to continue to hold itself ready to coöperate with other associations or bodies engaged in conservation work. The chairman also begs to suggest, as perhaps of far more promise if carried out, that each member contribute his part, individually and through any municipal bodies or private companies with which he may be connected, toward the actual work of conservation. This may be done by continuing the campaign against water waste and for wise utilization of water resources, and also by practicing an intelligent economy in the use of the metal, coal, and timber supplies of the country. Coal, in particular, affords a great field for saving, as every one knows who is familiar with the careless and inefficient way in which it is burned at many water-works pumping stations.

After water and wood, the greatest chance for the members of this Association to give practical every-day aid to conservation work is perhaps in connection with forest products. As a rule this opportunity does not pertain to the use of forest products so much as on their increase by planting and their improvement and conservation by care of forests on water-works drainage areas. Already a considerable amount of forestry work of this kind has been done, but the opportunities, instead of being exhausted, are hardly as yet entered upon. Whatever one's opinions may be as to the recently much-discussed question of the relation between forests and stream flow, probably all will agree that planting trees on water-works drainage areas would be beneficial to public water supplies in more ways than one, besides putting to profitable use land which is necessary for the sanitary protection of water supplies, but which otherwise could scarcely be made to produce a revenue. Of course any revenue of this kind will not become available for years to come. It is for this reason that recourse must be had chiefly to governmental agencies for the planting of forest trees.

Perhaps it will be appropriate to raise the question here why there has thus far been so little development of water-power or hydro-electric power in connection with public water supplies. Such opportunities do not present themselves, by any means, to every water-works authority, but there have been several notable opportunities of the kind which for some mysterious reason have not been seized. The studies of available water-power which have recently been undertaken by the New York State Water Supply Commission in connection with water storage and flood prevention are worthy of careful attention in other states. It is high time that our commonwealths realized that in the water of their streams and lakes they have a valuable business asset for future generations. It may be noted at this point that the act creating the present State Water Supply Commission of New Jersey provides that the state shall receive a revenue for all water taken for municipal purposes in

excess of one hundred gallons per capita per day, the rate to be fixed in each by the commission at a price of $1 to $10 per one million gallons.

Finally it may be noted that there can be no intelligent conservation of anything without knowing the exact nature and extent of that thing. It would seem that a new census of water power, and also a timber census would be highly useful, and that one or both of these might be properly advocated, either now or in the near future, by this Association. Perhaps more important than a water-power census is the securing of more extended and accurate records of everything pertaining to the yield of surface and underground waters.

M. N. BAKER, *Chairman.*

THE PRESIDENT. It seems to be necessary that all the committees should be granted further time, and it is willingly done.

ELECTION OF OFFICERS.

Mr. R. C. P. Coggeshall, in behalf of the tellers appointed to canvass ballots for officers for the ensuing year, submitted the following report:

BOSTON, MASS., January 13, 1909.

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — Your committee appointed by your President to open, verify, assort, and count the ballots cast for officers of this Association for the year 1909 have attended to the duty assigned them, and beg leave to report the following as the result of their canvass:

Whole number of ballots verified	250
Complete blanks	7
For President.	
ROBERT J. THOMAS	238
M. N. BAKER	1
E. W. KENT	1
For Vice-Presidents.	
GEORGE A. KING	235
WILLIAM F. SULLIVAN	232
GEORGE A. STACY	232
ALLEN HAZEN	238
WILLIAM C. HAWLEY	231
ERMON M. PECK	233
LEONARD METCALF	1
F. P. STEARNS	1
For Secretary.	
WILLARD KENT	243

For Treasurer.

LEWIS M. BANCROFT 242

For Editor.

RICHARD K. HALE 237
CHARLES W. SHERMAN 1

For Advertising Agent.

CHARLES W. SHERMAN 240
RICHARD K. HALE 1

For Additional Members of Executive Committee.

GEORGE W. BATCHELDER 236
FRANK L. FULLER 233
EDMUND W. KENT 237
E. C. BROOKS 4

For Finance Committee.

GEORGE CASSELL 239
JOHN C. CHASE 239
HUGH MCLEAN 238

Respectfully submitted,

R. C. P. COGGESHALL.
F. J. GIFFORD.

The President declared the officers elected, and then extended to Mr. Thomas, the new President, his personal congratulations and presented him to the Association.

MR. THOMAS. *Mr. President and Gentlemen:* I thank the members of the Association for this mark of their confidence and esteem in electing me President for the coming year. I assure you that I deeply appreciate the honor and promise to serve you to the best of my ability.

MR. M. F. COLLINS. I move a vote of thanks be tendered to the retiring President for the able, courteous, and impartial manner in which he has presided over our meetings during the past year.

The motion was put by Mr. Thomas, the President-elect, and was adopted with applause.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, February 10, 1909.

The President, Robert J. Thomas, in the chair. The following members and guests were present:

Members.

S. A. Agnew, L. M. Bancroft, G. W. Batchelder, J. E. Beals, F. D. Berry, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, E. C. Brooks, J. C. Chase, J. H. Child, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. O. Doane, John Doyle, E. D. Eldredge, C. R. Felton; J. H. Flynn, F. F. Forbes, W. E. Foss, F. L. Fuller, C. W. Gilbert, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, D. A. Heffernan, J. L. Howard, C. L. Howes, M. F. Hicks, F. M. Hutchinson, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, C. F. Knowlton, A. A. Knudson, N. A. McMillen, A. E. Martin, John Mayo, A. S. Merrill, F. E. Merrill, G. F. Merrill, William Naylor, F. L. Northrop, O. E. Parks, E. M. Peck, H. E. Royce, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, W. E. Smith, J. T. Stevens, W. F. Sullivan, L. A. Taylor, H. L. Thomas, R. J. Thomas, W H. Thomas, J. L. Tighe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. K. Walker, L. R. Washburn, J. C. Whitney, F. B. Wilkins, G. E. Winslow, W. H. Richards, — 74.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Harold L. Bond Company, by H. L. Bond and G. S. Hedge; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; F. H. Hayes Machinery Company, by F. H. Hayes; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Chas. Millar & Son Co., by Chas. F. Glavin; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; United States Cast-Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. W. Van Winkle. — 20.

Guests.

Mayor George H. Brown, of Lowell, Mass.; H. N. Ward, superintendent, Newport, R. I.; Edwin L. Burnap, superintendent, and Shepard B. Palmer,

engineer, Norwich, Conn.; N. F. Putnam, Street Department, Lowell, Mass.; Michael Doren and Eugene F. Proctor, Brookline, Mass.; Joseph W. Cowles, Wm. H. Lott, and F. Elwood Smith, Edison Electric Illuminating Company, Boston, Mass.; George R. Stetson, New Bedford, Mass.; John Gray Manuel, assistant superintendent, Natick, Mass.; O. L. Lunn, Beverly, Mass.; R. L. Whipple, assistant city engineer, North Adams, Mass.; Wm. Jameson, water commissioner, Chicopee, Mass.; Mr. Cook, state forester assistant, Boston, Mass.; H. Richards, New London, Conn. — 18.

THE PRESIDENT. We have as a guest here to-day a man of whom you have all heard or read about, especially those of you who belong in Massachusetts. You have read about the campaign he made for mayor in a certain one of our cities; how, without political experience and without funds, and in the face of an antagonistic press, he was elected by a larger vote than any candidate ever got before for mayor of that city. Since he has been mayor he has shown, although never having held municipal office before, a wonderful grasp of city affairs, and he has shown unmistakably, what many public officials lack, the courage of his convictions, and the courage to put his convictions into execution. It gives me great pleasure to introduce to you to-day the Hon. George H. Brown, Mayor of Lowell. [Applause.]

MAYOR BROWN. *Mr. President, Members of the New England Water Works Association, and Guests:* I assure you that it gives me great pleasure to be present here to-day. When my friend your president invited me to come, I said, "You are not going to ask me to make an address, are you?" "Well," he said," we will let you out easily; you can just say you are pleased to be there and thank them very much."

But he gave me one thought when he said just now that I had the courage of my convictions. I believe that the chief executive of any city, and not only the chief executive, but the other city officials, — you gentlemen who represent your departments in the different cities, you who are the heads of those departments, — that it is necessary for you to have the courage of your convictions. I have had what you may term a common education, and I have those other qualifications which the average man has who runs for public office; but beyond that I feel that I am wholly lacking. But there is one thing I have in my mind, and that is to

do my duty faithfully and to have the courage of my convictions all the time. I had an honest purpose when I went out before the citizens of my city and asked them to elect me as their chief executive, and I said, " If you elect me as your mayor I will do so and so "; and as the mayor, and as the servant of the city of Lowell, I am trying to put into force what I promised. I said to the people of Lowell, " If you will elect me as your mayor, I will never betray you," and as their mayor I am not going to betray the trust which was reposed in me when I was elected to the high office of chief executive of the city of Lowell.

So I say to you to-day, gentlemen, do not betray the trust that is reposed in you; have the courage of your convictions all the time; have an honest purpose, taking for your pattern our martyred President, the one hundredth anniversary of whose birth we will celebrate on Friday. Do your duty faithfully and honestly, as Lincoln did his. The men who do their duty and have the courage of their convictions wear well and will wear all the time. I haven't any peculiar ability. They tell me that throughout the state of Massachusetts and in other places people read about Brown; but Brown has no exceptional qualifications; he has no real ability. All Brown has got is the courage of his convictions and an honest purpose, and he is trying to do his duty; that is all.

So you see that if a man tries to do his duty he wears well, he wears all the time, like our honored President Roosevelt, who wears well and will continue to wear well. So all men who are acting in an official capacity, if they do their duty, they will wear well and will be remembered; but when they fail to do their duty, when they betray the trust of the people, they will be forgotten.

I am much interested in one of the topics you have on your program — the grounding of electric light wires on water pipes. We have that in Lowell. I had the head of the electric light company in Lowell in my office the other day, and I called his attention to this matter. I said to him, " We want better service from your corporation." He went into the cost of furnishing that better service, and I said, " There will be no cost to the city; it is going to be free from your corporation. Lowell is giving you and has been giving you quite a consideration in letting you ground your wires on our water pipes, and you have got to give us better service. You have got to give us what we want, and if you do not,

I will see to it that you don't ground your wires on our pipes any longer." I am not going into the matter any further, and I only mention this to let you know that I am interested in the subject in Lowell, and I had that in mind more than anything else in coming down here, for I wanted to get some information upon this subject. I am not a good speaker, as you have discovered; I think I am a better listener. I thank you.

THE PRESIDENT. After listening to the Mayor of Lowell you may think that I had a lot of presumption to tell him what to say. [Laughter.] You undoubtedly are all satisfied that he knows just what to say and how to say it. We will now proceed with the business of the meeting, and the first matter is the consideration of applications for membership.

The Secretary read the names of the following applicants for membership, all of whom had been duly approved by the Executive Committee:

Karl H. Hyde, civil engineer, Attleboro, Mass.; Warren E. Tarbell, East Brookfield, Mass., water commissioner, Brookfield; Frank L. Rector, Brooklyn, N. Y., bacteriologist, Great Bear Spring Company, Brooklyn, N. Y.; J. P. A. Laforest, Levis, Canada, engaged in water works construction; William Sinclair Bacot, Morristown, N. Y., formerly water works engineer and manager, but not in active practice at present; A. P. Negus, New Bedford, Mass., pumping engineer of the New Bedford Water Works Department.

On motion of Mr. Coggeshall, the Secretary was directed to cast one ballot in favor of the applicants, and he having done so they were declared elected members of the Association.

There were two papers on the program for the afternoon, the first on "Lead Covered Cables a Cause of Electrolysis of Water Pipes," by A. A. Knudson, electrical engineer, New York City; and the second on "Grounding Electric Light Wires on Water Pipes," by Frank E. Merrill, water commissioner, Somerville, Mass. Mr. William H. Lott, Superintendent of Right of Way and Street Lighting of the Boston Edison Electric Illuminating Company; Mr. Joseph W. Cowles, superintendent of installation, and Mr. F. Ellwood Smith, also of the Edison Company, were present as guests of Mr. Merrill, and spoke upon the matter presented in

Mr. Merrill's paper, and answered numerous questions which were asked by members of the Association.

The President extended the thanks of the Association to the officials of the Edison Company for the information which they had given, and expressed his pleasure at the large attendance.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 9, 1908, at 11.30 A.M.

Present: President Alfred E. Martin, and members Michael F. Collins, George A. Stacy, Lewis M. Bancroft, George A. King, George W. Batchelder, Robert J. Thomas, Charles W. Sherman, William F. Sullivan, and Willard Kent.

The following applications were received and recommended for membership, viz., O. C. Merrill, civil engineer, Berkeley, Cal., and John C. Otis, M.D., president Board of Public Works, Poughkeepsie, N. Y.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 13, 1909.

Present: President Alfred E. Martin, and members D. N. Tower, George A. King, Robert J. Thomas, Michael F. Collins, George W. Batchelder, George A. Stacy, Charles W. Sherman, William F. Sullivan, Lewis M. Bancroft, and Willard Kent.

The following applications were received and recommended for membership, viz.:

For members: Herbert D. Pease, director New York State Hygienic Laboratory, Albany, N. Y.; Arthur E. O'Neil, superintendent pumping stations, Metropolitan Water Works, Watertown, Mass.; Millard F. Hicks, treasurer Portland Water District, Portland, Me.; Leonard M. Wachter, sanitary chemist, New York State Department of Health, Albany, N. Y.; Charles H. Tuttle, superintendent Bristol and Warren Water Works, Bristol, R. I.; Fred M. Hutchinson, engineer and foreman water works, Somerville, Mass.

For Associate: F. H. Hayes Machinery Company, pumping machinery, Boston, Mass.

Voted: That a committee of three, not members of the Executive Committee, be appointed by the President to investigate hotel accommodations with a view to improvement.

Voted: That the Executive Committee be and hereby is made a reception committee to welcome new members and visitors.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, February 10, 1909, at 11.30 A.M.

Present: President Robert J. Thomas, and members George A. King, William F. Sullivan, Ermon M. Peck, George W. Batchelder, Frank L. Fuller, Edmund W. Kent, Lewis M. Bancroft, Charles W. Sherman, and Willard Kent.

Six applications were received and recommended for membership, viz., J. P. Albert Laforest, civil engineer, Levis, Canada; Frank L. Rector, M.D., bacteriologist, Brooklyn, N. Y.; Warren E. Tarbell, water commissioner, Brookfield, Mass.; Karl H. Hyde, civil engineer, Attleboro, Mass.; A. S. Negus, pumping engineer, New Bedford, Mass.; and William Sinclair Bacot, civil engineer, Morristown, N. J.

The subject of place for holding the next annual convention was discussed. The committee to ascertain accommodations at Bangor made informal report, and Mr. Ermon M. Peck was made a committee to make similar investigations with reference to New Haven, Conn.

Messrs. Charles W. Sherman, Richard K. Hale, and William E. Maybury were constituted a committee to arrange for the June excursion.

The committee on hotel accommodations reported that they have made satisfactory arrangements for service, and recommended that a committee be appointed to see that those arrangements are carried out. Mr. George W. Batchelder was made that committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

EDWIN REYNOLDS died at his home in Milwaukee on February 19, 1909.

Mr. Reynolds was born in Mansfield, Conn., on March 23, 1831. He was the son of Clarissa Huntington and Christopher Reynolds, and a direct descendant of William Reynolds, who came from Gloucestershire, England, in 1673, settling in Rhode Island.

Mr. Reynolds, after leaving the public schools, became an apprentice to a machinist. Later he worked in machine shops in Connecticut, Massachusetts, and Ohio, finally becoming superintendent of the machine shops of Steadman & Co., of Aurora, Ind., after which he again returned to Connecticut. He remained for six years in that state as well as in Boston and New York, during which time he worked on the machinery of Ericsson's *Monitor*, which played such an important part in the Civil War.

After the war he entered the Corliss Steam Engine Company, of Providence, R. I., and in 1871 was made general superintendent of that company.

In 1877 he left the Corliss Company to work with Edward P. Allis & Co., of Milwaukee. Later, on the reorganization of that company, he became director, vice-president, and general superintendent. This position he held until 1901, when he became director and chief engineer of the Allis-Chalmers Company, which was organized largely through his efforts.

He retained this position until 1906, when, his health failing, he had to give up active business, though still keeping his title of chief engineer.

Among some of Mr. Reynolds's designs are the Reynolds-Corliss valve gears used by every builder of Corliss engines; a direct-acting metallic valve blowing engine, which revolutionized the construction of blowing engines and air compressors; and a steam stamp for

crushing ore. Mr. Reynolds also designed some of the largest hoisting engines in the country.

The modern "high-duty" triple expansion pumping engine was another design original with Mr. Reynolds. At present this represents universal practice, but at the time it was introduced it was a radical departure from the type of machinery then in use.

Mr. Reynolds designed many of the large engines for electrical work, among which may be mentioned the 12 000 horse-power engines of the New York subway and Manhattan elevated power stations.

Mr. Reynolds was president of the American Society of Mechanical Engineers in 1901 and a member of the Executive Committee of the same society. He received a degree of LL.D. from the University of Wisconsin.

Mr. Reynolds was elected an honorary member of the New England Water Works Association on September 13, 1906.

BOOK REVIEW.

LABORATORY NOTES ON INDUSTRIAL WATER ANALYSIS. A Survey Course for Engineers. By Ellen H. Richards, Instructor in Sanitary Chemistry, Massachusetts Institute of Technology. iii + 49 pages. 6 x 9 inches. New York: John Wiley & Sons. Cloth, 50 cents net.

This little book is presented in the form of laboratory exercises, showing in condensed form the procedures of water analysis.

The author classifies water into three main divisions, — scale forming, moderate scale forming, and non-scale forming, — and offers the simpler tests for placing the water under examination in one of these groups; after that follows the procedure for the more exact methods of determining the constituents of the sample.

To an engineer who has a slight knowledge of chemistry, this book offers in a condensed form the standard methods used for determining the kind and quantity of the more important substances in a water, that are injurious to boilers.

To the student the book gives a condensed survey of a subject which undoubtedly will be of value to him in his future practice.

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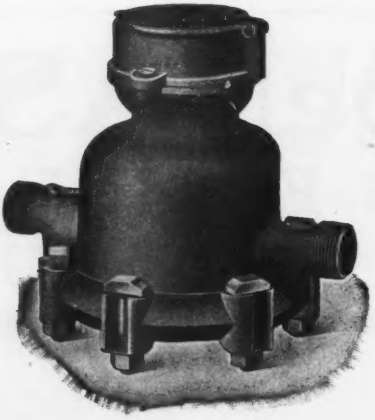

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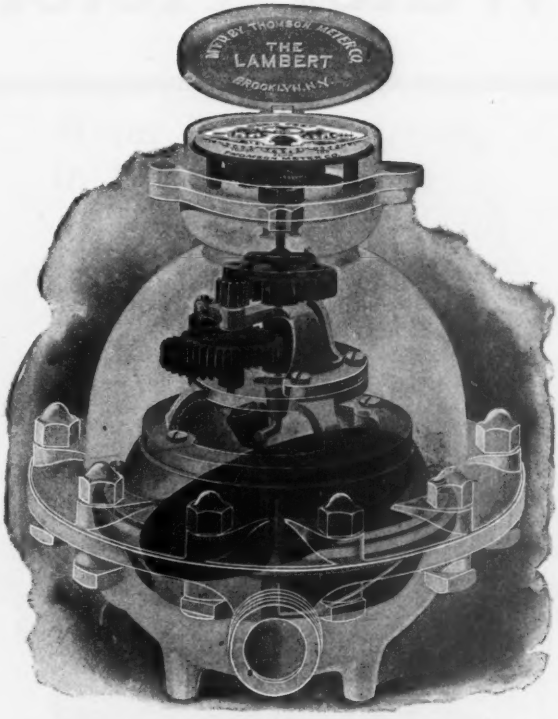

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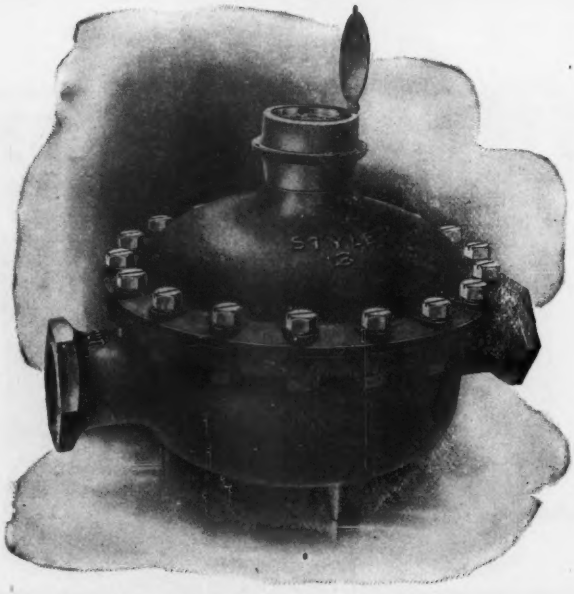

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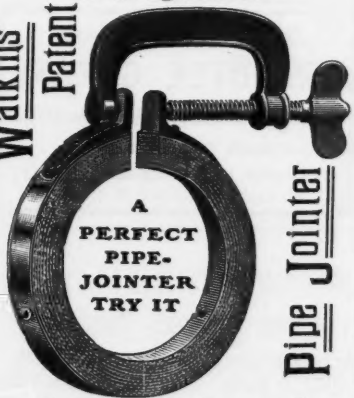

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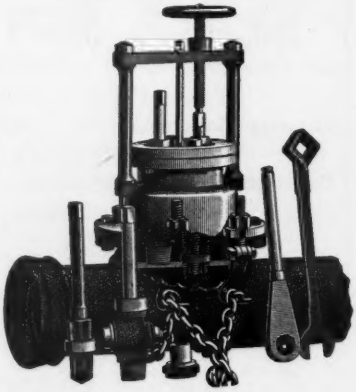

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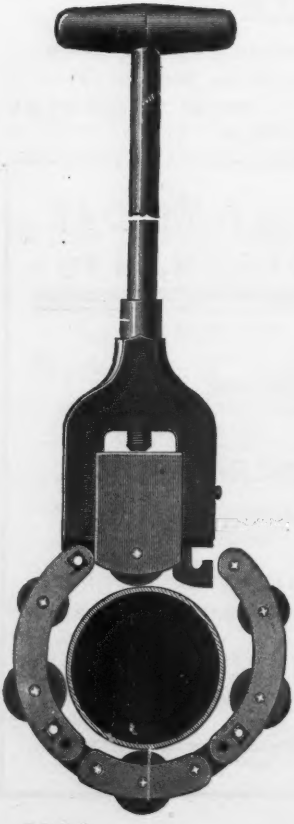

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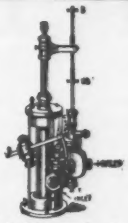

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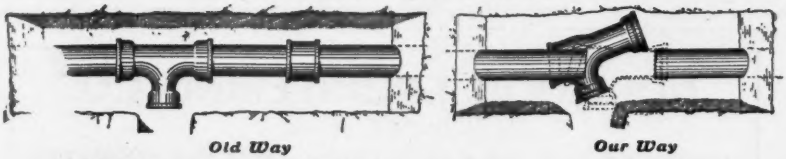

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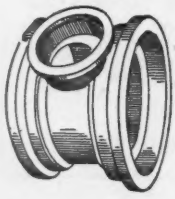

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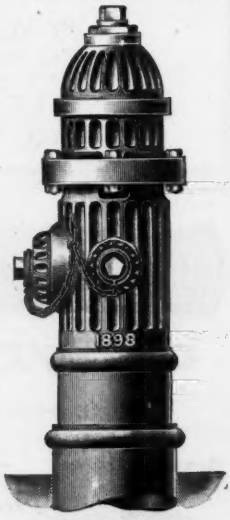

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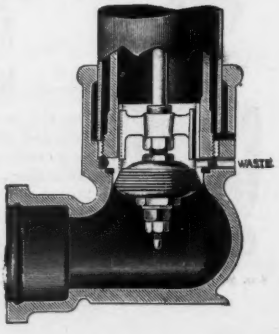

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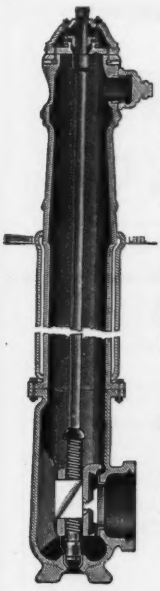

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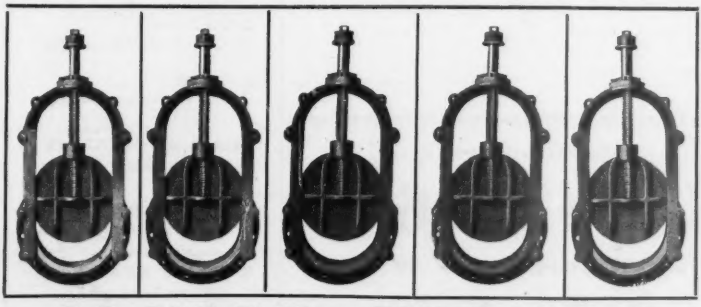

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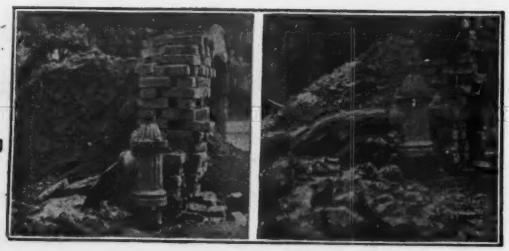

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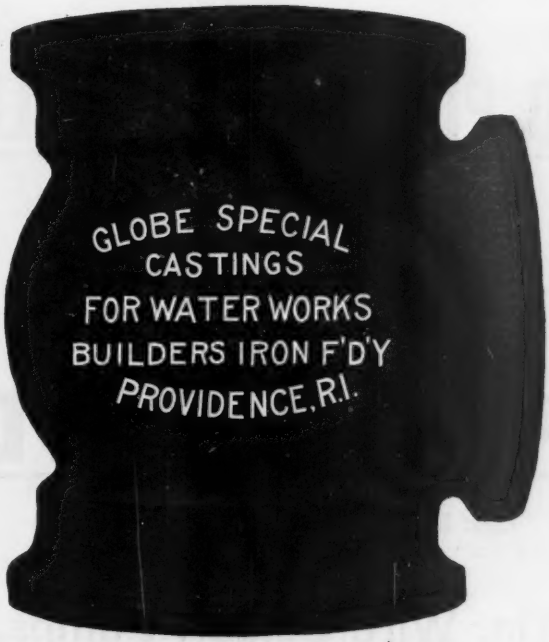

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